Nuclear Power

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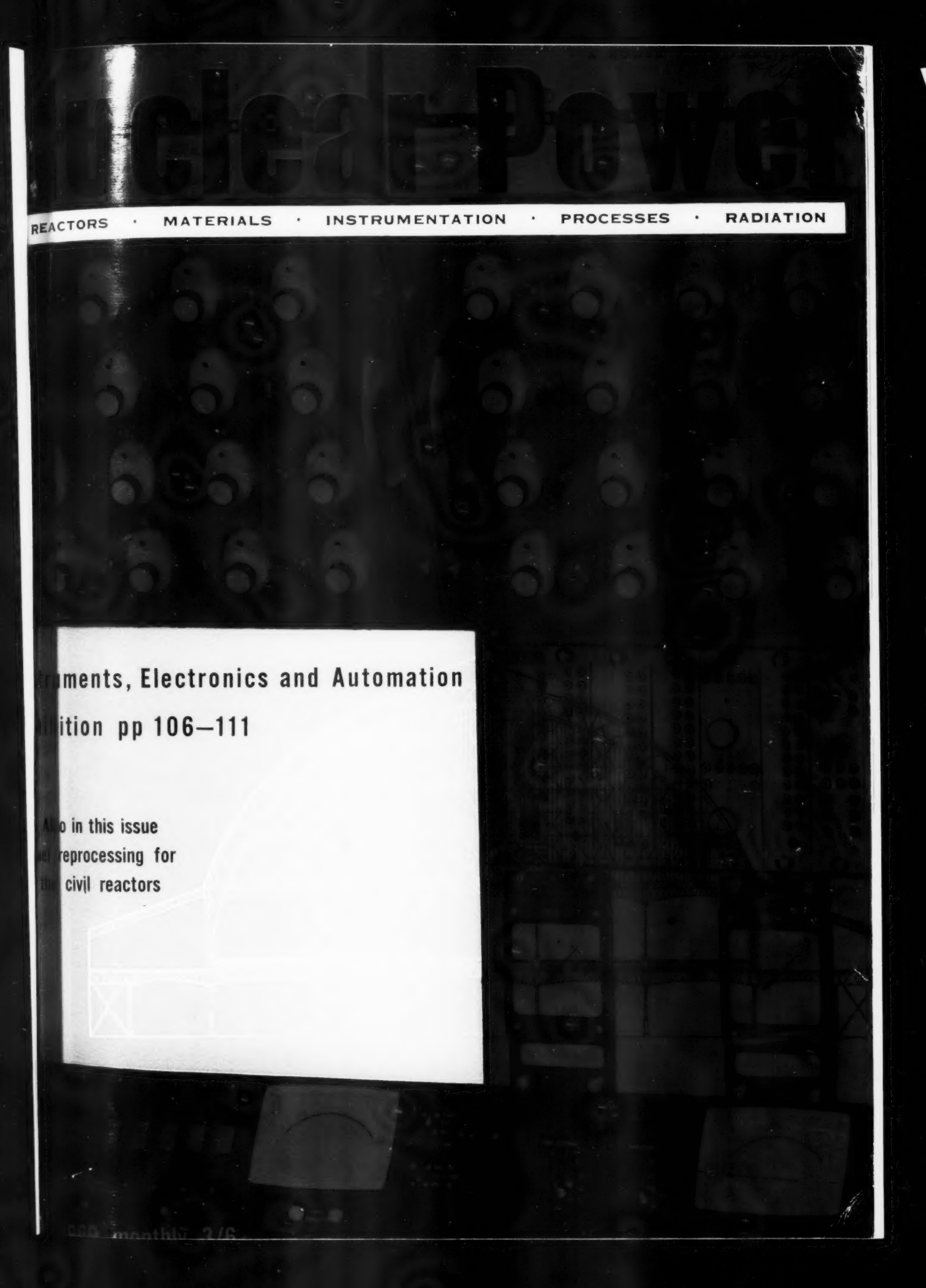

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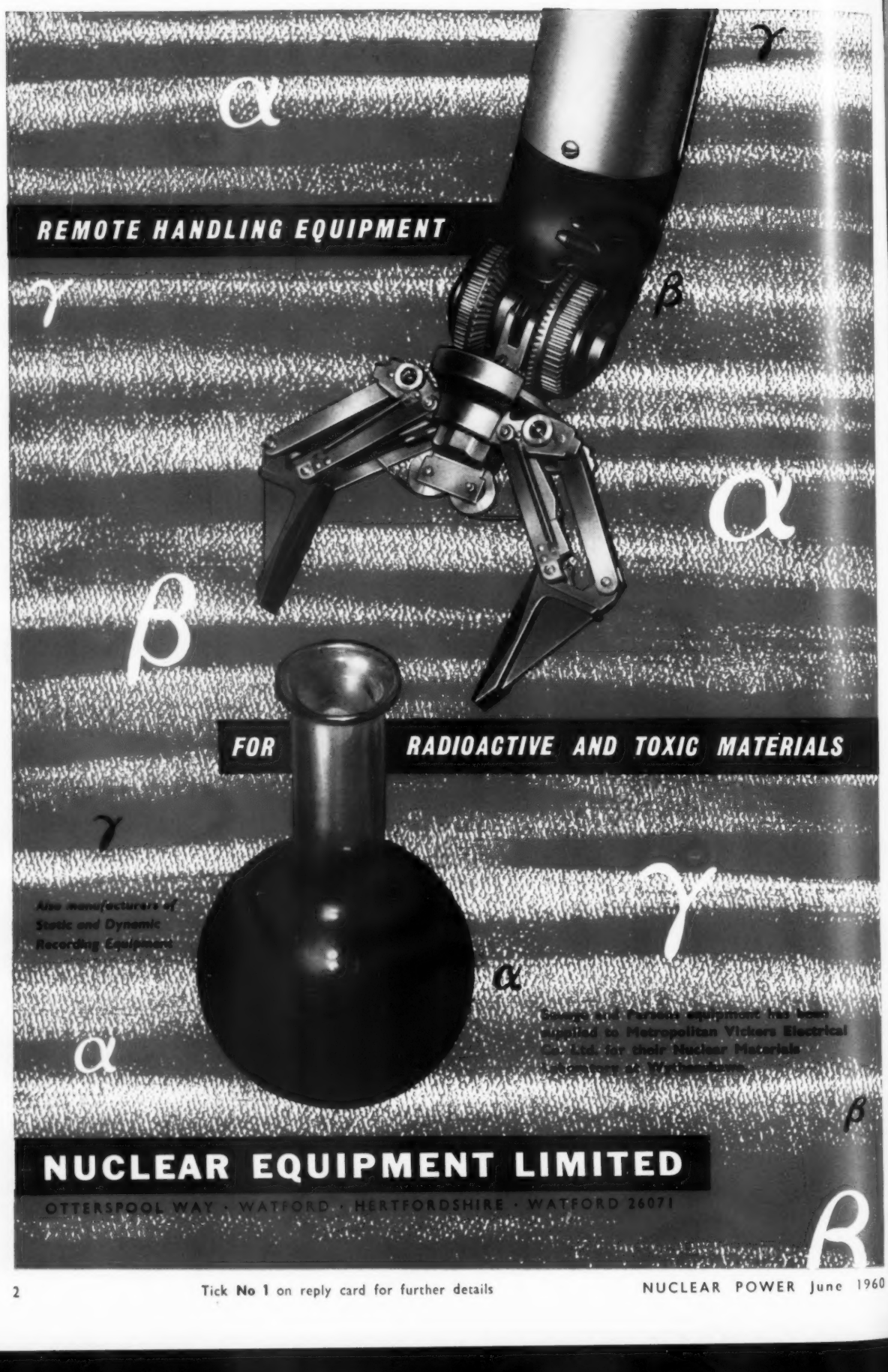
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VOL 5 NO 50 JUNE 1960

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International NU-SWIFT News

No. 1

HAVE YOU MET THESE PEOPLE?

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1. The new 16-storey skyscraper in BASLE, Switzerland, built and occupied by GEIGY, the world-famous chemical concern, has been equipped with Nu-Swift extinguishers.

2. Old-fashioned chemical extinguishers in the SHELL-MEX Building, in the STRAND, LONDON, largest office building in the Commonwealth, have been superseded by reliable Nu-Swift equipment. The 8,008,462 cubic feet of this giant edifice, built in 1933, which is served by 16 lifts, 6 oil-fired boilers and 22 miles of water pipes, are now protected by a total of 261 Nu-Swift extinguishers.

3. Peppered with skyscrapers of daring, colourful design, exotic CAIRO, which now has a population of nearly 3 million, once again boasts a SHEPHEARD'S HOTEL, if possible even more cosmopolitan than its predecessor, burned down in riots a few years back. The first consignment of Nu-Swift extinguishers admitted into the UNITED ARAB REPUBLIC since 1956 has been allocated to the lovely new hotel overlooking the Nile, and which, although not yet completely finished, is already open to the public.

4. MONTEGO BAY AIRPORT on the North Coast of Jamaica, well-known to sun-hungry socialites in U.S.A. and Britain, is now safeguarded by Nu-Swift. So is the exclusive TOWER ISLE HOTEL.

5. Recognition of the POWERFUL SHOCK EFFECT of DRY POWDER, when used in fire fighting, accounts for the recent decision of the progressive VIENNA FIRE BRIGADE to install Nu-Swift Dry Powder Extinguishers ON THEIR FIRE ENGINES.

6. In STOCKHOLM, enchanting capital of beautiful Sweden, a rush order for 1¼ tons of extinguishers was recently executed by Nu-Swift sales concessionaires in 6 hours. The number of extinguishers required was 60. SKF, ASEA and STORA KOPPARBERGS BERGSLAGS A/B (the oldest industrial undertaking in the world), are among other industrial giants, in fast-moving Sweden, who have standardized on reliable Nu-Swift Dry Powder Extinguishers.

7. If overtaken by the LAKE POLICE while speeding on the 20-mile long LAKE ZURICH, you will find their patrol boats equipped with Elland-made Nu-Swift Dry Powder Extinguishers, Model 1604. Ashore, this also applies to the police cars of the City and Kanton of busy and prosperous ZURICH.

8. Direct rail connections link COPENHAGEN with Rome, Paris, Vienna, Venice, etc. THE DANISH STATE RAILWAYS have now equipped all international coaches starting from the up-to-date capital of Denmark, with Nu-Swift.

9. After exhaustive tests, extending over several years, the AUSTRALIAN ARMY have satisfied themselves that Nu-Swift Dry Powder Extinguisher, Model 1604, meets their exacting requirements. The first orders have been placed.

10. More than 50% of all new NORWEGIAN vessels, mainly TANKERS, are protected by Nu-Swift.

11. The underground aeroplane factories of SAAB (SVENSKA AEROPLANE A/B) Linköping, Sweden, are protected by Nu-Swift. So are the naval vessels in the ATOM-BOMB-PROOF UNDERGROUND HARBOUR near Stockholm, built into the mountain by the cautious Swedes.

12. In far-off FIJI, where cannibalism was rife within living memory, the recently constructed BROADCASTING STATION is protected against fire by Nu-Swift. So is the new AUTOMATIC TELEPHONE EXCHANGE.

13. An animated correspondence with G. BERNARD SHAW resulted in 1944 from an enquiry by the ever-alert but critical sage. Asked by Shaw why, in our letter of reply, no prices were quoted, a cheeky Nu-swift clerk retorted that "We thought you wanted to protect your life, not your purse. Does price matter when your life is at stake?" G.B.S. rose to the bait by replying: "Please treat me as a prospective customer, not as a back-chat comedian."

14. SWISS FEDERAL RAILWAYS, one of the most efficient and modern railway systems in the world, have placed their first orders for Nu-Swift extinguishers.

15. Mr. W. J. SCOTT, Q.C., FIRE MARSHAL OF THE PROVINCE OF ONTARIO, during a recent lightning trip to Europe, as Dominion Government NATO delegate, included Elland in his itinerary. On his return, having also called in London, Paris, Rome and Madrid, he stated that the visit to Elland remained one of the highlights of his European tour, and caused orders to be placed for sample and demonstration extinguishers for the new Ontario Fire Service College at GRAVENHURST, 80 miles from TORONTO.

16. Since THE SUDAN gained her independence, the authorities have decided to standardize on Nu-Swift. The first orders have arrived from Khartoum.

17. In KUWAIT, fabulously wealthy Arabian oil-well state on the Persian Gulf, police and army cars are now all protected by Nu-Swift.

18. In NIGERIA, shortly expected to achieve its independence, TRAINS AND HOSPITALS are equipped with Nu-Swift. Climate is hot and humid.

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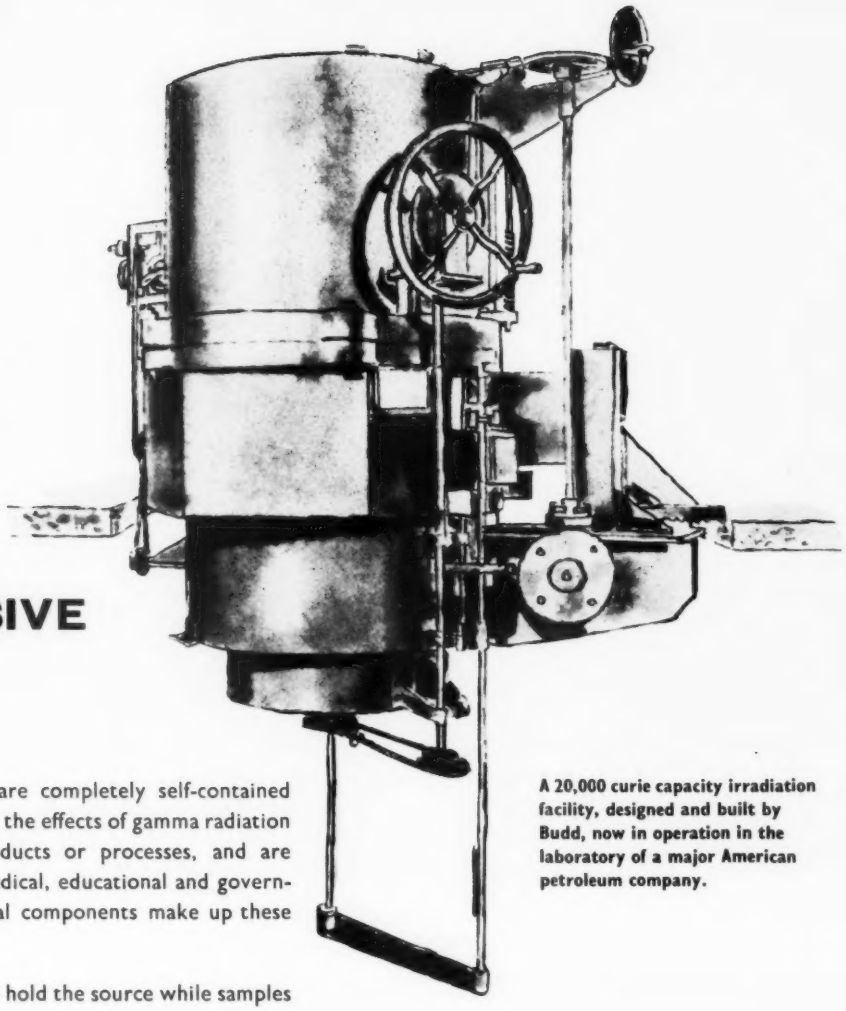

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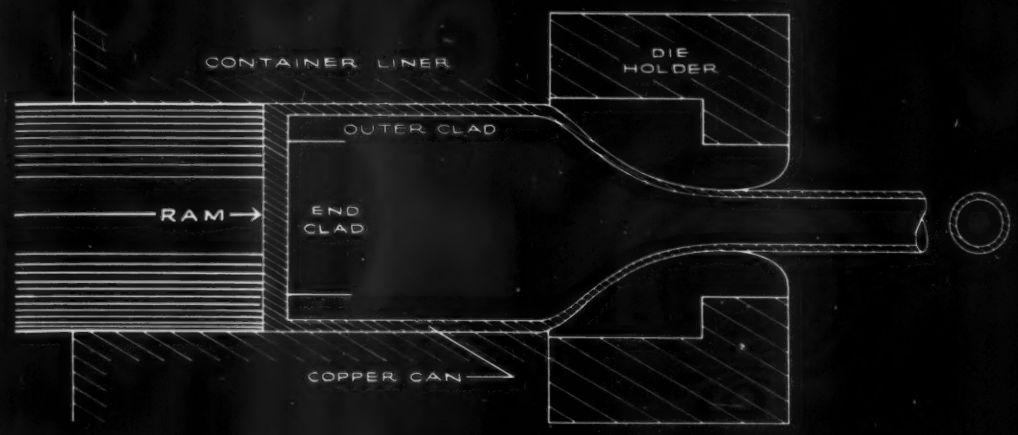
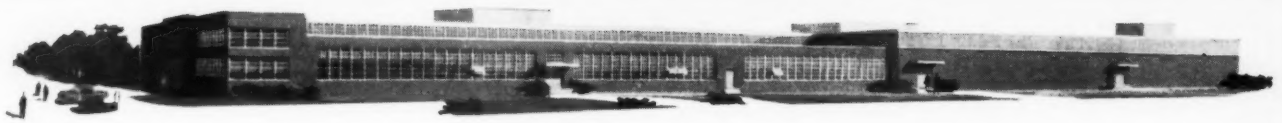
NEWARK NOTTS





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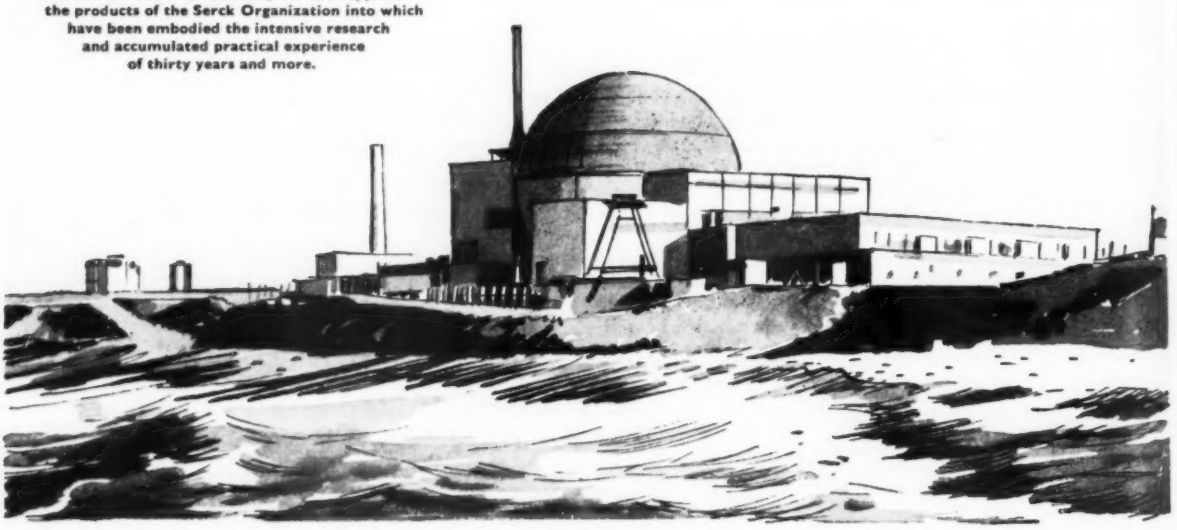

A V.I.P. certainly, not present in person but very much in spirit. A man whom the other three have probably never met and may not even know. A man who is mostly out of sight but never, never out of mind. THEY are the Acheson heads of Sales, Production and Research. HE is a customer—you, perhaps—and at this conference the man of the moment. He knows us well, otherwise he would not be present (spiritually). He knows us well, yet almost certainly not well enough. He may not realise how much more we are prepared to do to help him. He knows we were the first and are the foremost manufacturers of colloidal graphite and MoS_2. He knows of "Oildag" colloidal graphite in oil and "Aquadag" colloidal graphite in water. But does he know about the scores of other Acheson dispersions, of silver, lead and boron, for instance, or vermiculite, glass and mica? Does he know that we have tailor-made, to the most stringent specifications, special dispersions for the UKAEA, Government and Service departments, and many world-famous industrial concerns? If he *does* know these things we apologise for this reminder. If he doesn't, we'll leave one final point with him: there's more in the Acheson service than meets the (regular or potential) customer's eye. Naturally we would be delighted to tell him about it.

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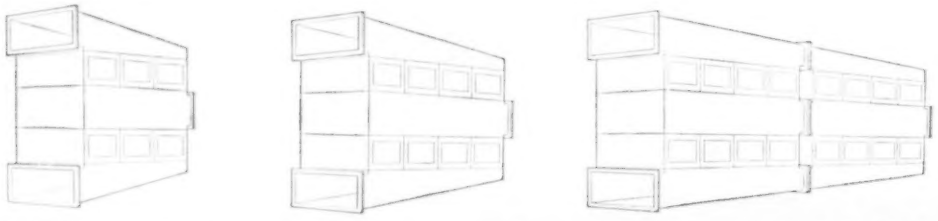

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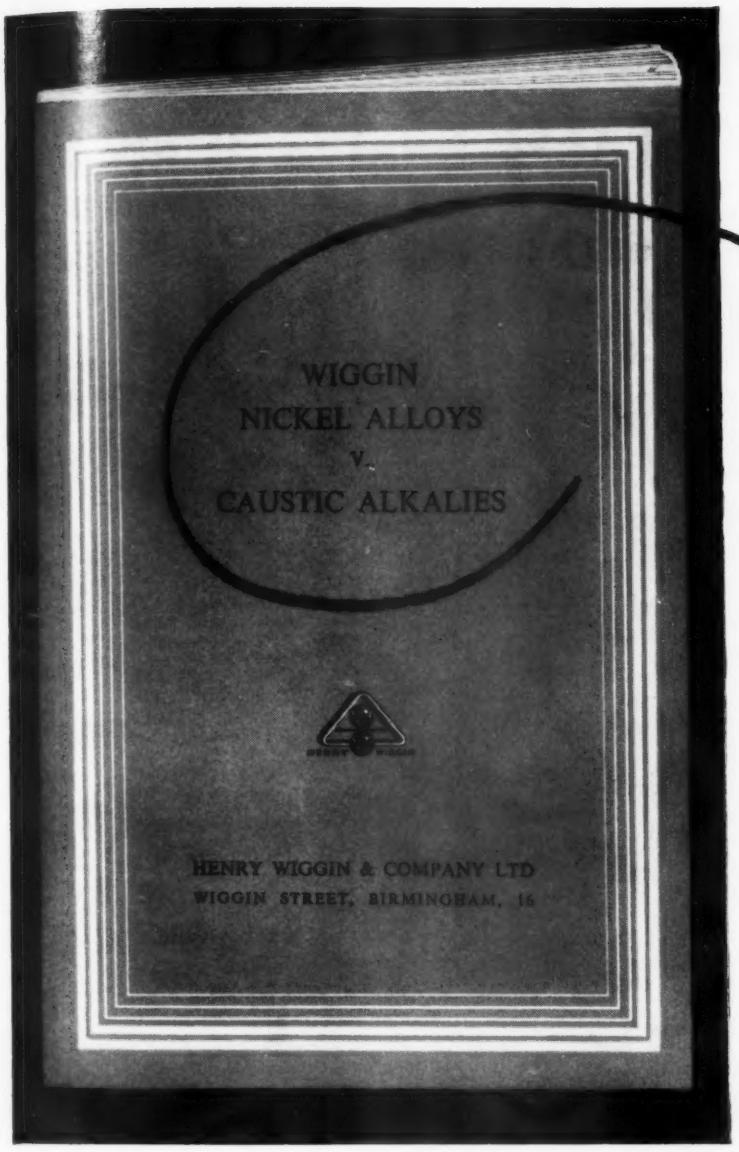

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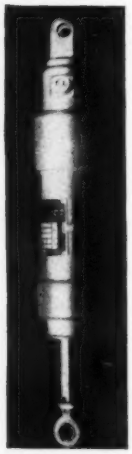

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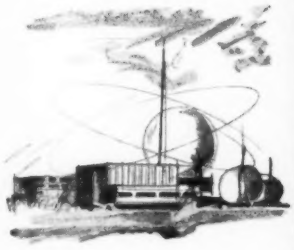

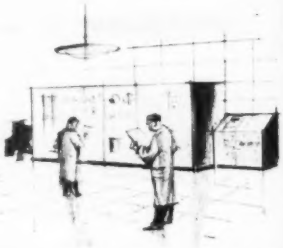

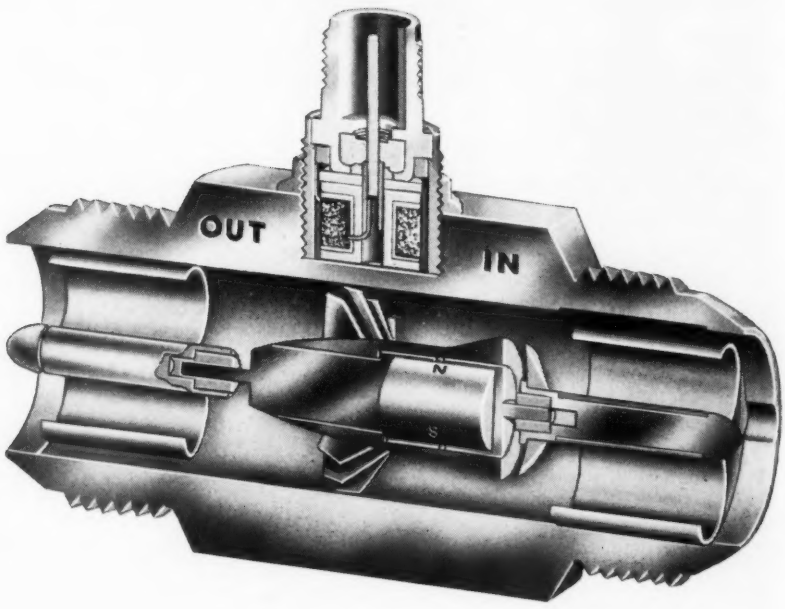

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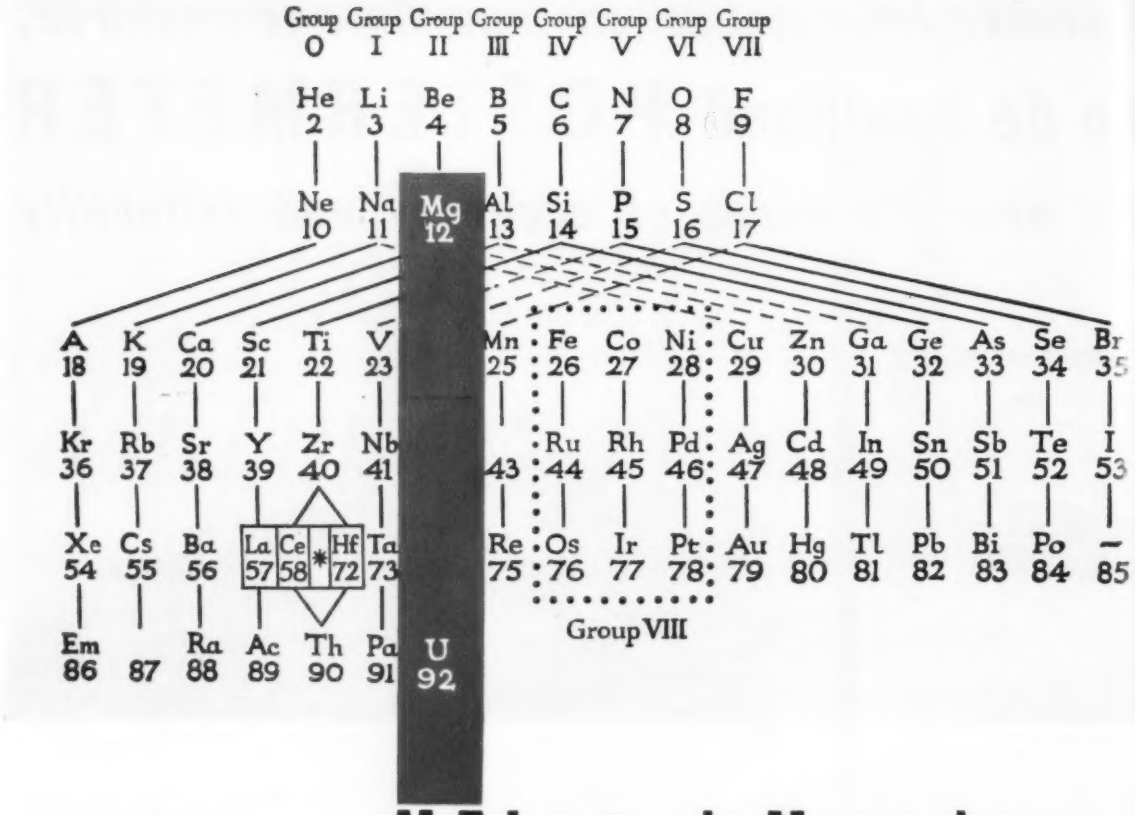
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London Office: 5 Charles II Street St. James's SW1
Magnesium Elektron, Inc. New York 20 USA

Power-made to measure!

The ever-increasing demand for electricity must be met and, if this country is to survive as a prosperous and expanding industrial nation, it must be met as economically as possible.

The problem is being solved in two ways—by increased technical efficiency in normal power station operation and by development of nuclear power. New power stations, whether they burn coal or depend on nuclear energy, are progressively more and more efficient.

Coal will long continue to be our main source of power. The present surplus is only temporary. In the foreseeable future the expanding demand for power will exceed the available supply of home-produced coal. That is why Britain has a nuclear power programme which is the largest and most progressive in the world.

C E G B

THE CENTRAL ELECTRICITY GENERATING BOARD

CIMENT FONDU
Regd Trade Mark
ALUMINOUS CEMENT

For

*HEAT-RESISTANT CONCRETE

WITH SPECIAL PROPERTIES FOR SPECIAL PROBLEMS

Exceptional cold strength at 24 hours and permanent residual strength for structural purposes at elevated temperatures.

Great thermal shock resistance.
Volume stability at temperature.
Low thermal conductivity.
Highly resistant to chemical attack.

Shielding action at elevated temperatures due to high proportion of combined water.

(*Temperature limit up to 1350°C, dependent on type of heat-resistant aggregate employed !)

Our Technical Dept. is entirely at your disposal for further specific information

CIMENT FONDU
Regd Trade Mark
ALUMINOUS CEMENT

FOR SPEED—STRENGTH

RESISTANCE

REFRACTORINESS

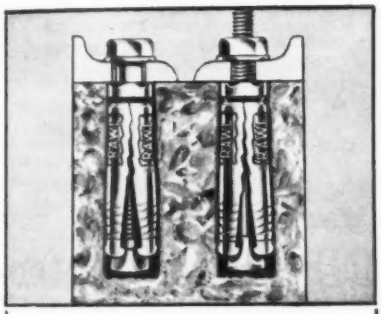
Manufactured by
LAFARGE ALUMINOUS CEMENT COMPANY LTD
73, Brook Street, London, W.1 Tel: MAY 8546

For operating temperatures up to 1800°C, or when a refractory resistant to reducing conditions is required, use Super-Duty Refractory Concretes made with SECAR 250, a pure white calcium-aluminate cement, free from iron oxides. Write for details.

AP122

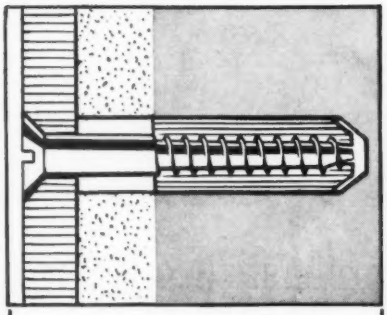
SOLVE YOUR FIXING PROBLEM WITH ONE OF THE 21

However tough or awkward the material into which you want to fix, or difficult the problem, there will be among the 21 TYPES OF RAWLPLUG FIXING DEVICES, the right answer. Speed and simplicity of application, reliability and complete security, coupled with the RIGHT solution to a problem, are the foundations of the RAWLPLUG FIXING TECHNIQUES.
A comprehensive catalogue showing these fixings in detail, together with their application, will gladly be forwarded to you on request.



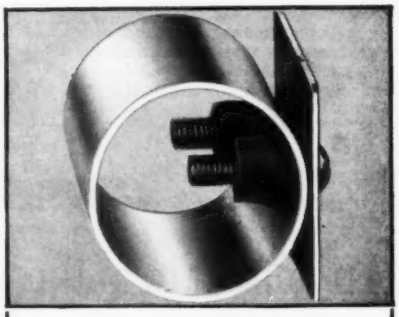
BOLT FIXINGS

With **RAWLBOLTS** a bolt fixing job is done in minutes, as against days by earlier methods. Simply drill the hole, drop in the **RAWLBOLT**, put into place the unit to be held, tighten up and the **RAWLBOLT** is ready to take the maximum load that the bolt, or the material into which it is fixed, will stand.
For extremely wet or corrosive locations, use Rawlplug Caulking **BOLT ANCHORS**; for securing metal threads in masonry—**RAWLTAMPS**. Where fixing points can be predetermined before pouring concrete, use **CEMENT-IN SOCKETS**, thus obviating the need for hole-boring.



SCREW FIXINGS

For making neat, absolutely firm screw fixings in masonry, indoors or out, the famous **RAWLPLUG** is still vastly quicker and more efficient than any alternative method. Rawlplugs are waterproof and quite unaffected by climatic conditions. They are available for all screw sizes up to $\frac{3}{4}$" diameter Coach Screws.
For fixings that are to be subjected to high temperatures, or in under-water conditions, use **WHITE BRONZE PLUGS** with stainless steel or cadmium plated steel screws. For fixings subject to corrosive fumes or liquids, use Rawlplug **LEAD SCREW ANCHORS** with stainless steel screws.



CAVITY FIXINGS

The **RAWLNUT**—an ingenious device for fixing into any hollow materials. Inserted and fixed from the outside, it forms its own anchorage within the cavity; and provides a vibration-proof, watertight and **AIRTIGHT** fixing. In addition a type can be supplied to give adequate protection to the screw **IN THE CAVITY.**
SPRING TOGGLES make firm fixings in thin and structurally weak materials such as plasterboard, ceilings, etc. The wings of the device spring apart behind the material and spread the load. **GRAVITY TOGGLES**, for use in hollow wall materials, position their toggles by the action of gravity.

THERE ARE 21 DIFFERENT TYPES OF

RAWLPLUG WALL PLUGS

FIXING DEVICES

and an all-inclusive range of high performance hole-boring tools, hand or power.

8617

THE RAWLPLUG COMPANY LIMITED • CROMWELL ROAD • LONDON, S.W.7

WANTED

An adequate and commensurate REWARD will be paid for information leading to the recapture of the above office junior who is under the delusion that she has lost the address of **ASSOCIATED LEAD** and who now fears that her employers are unable to obtain supplies of **LEAD, TIN, ANTIMONY AND THEIR ALLOYS; 99·999% PURE LEAD, TIN AND ANTIMONY; SOLDERS; ANTIFRICTION METALS; ANTIMONIAL LEAD; CABLE ALLOYS; LEAD SHEET & PIPE; DENSE LEAD SHIELDING FOR NUCLEAR WORK.** This girl is suffering from strong guilt feelings and may have assumed an alias.

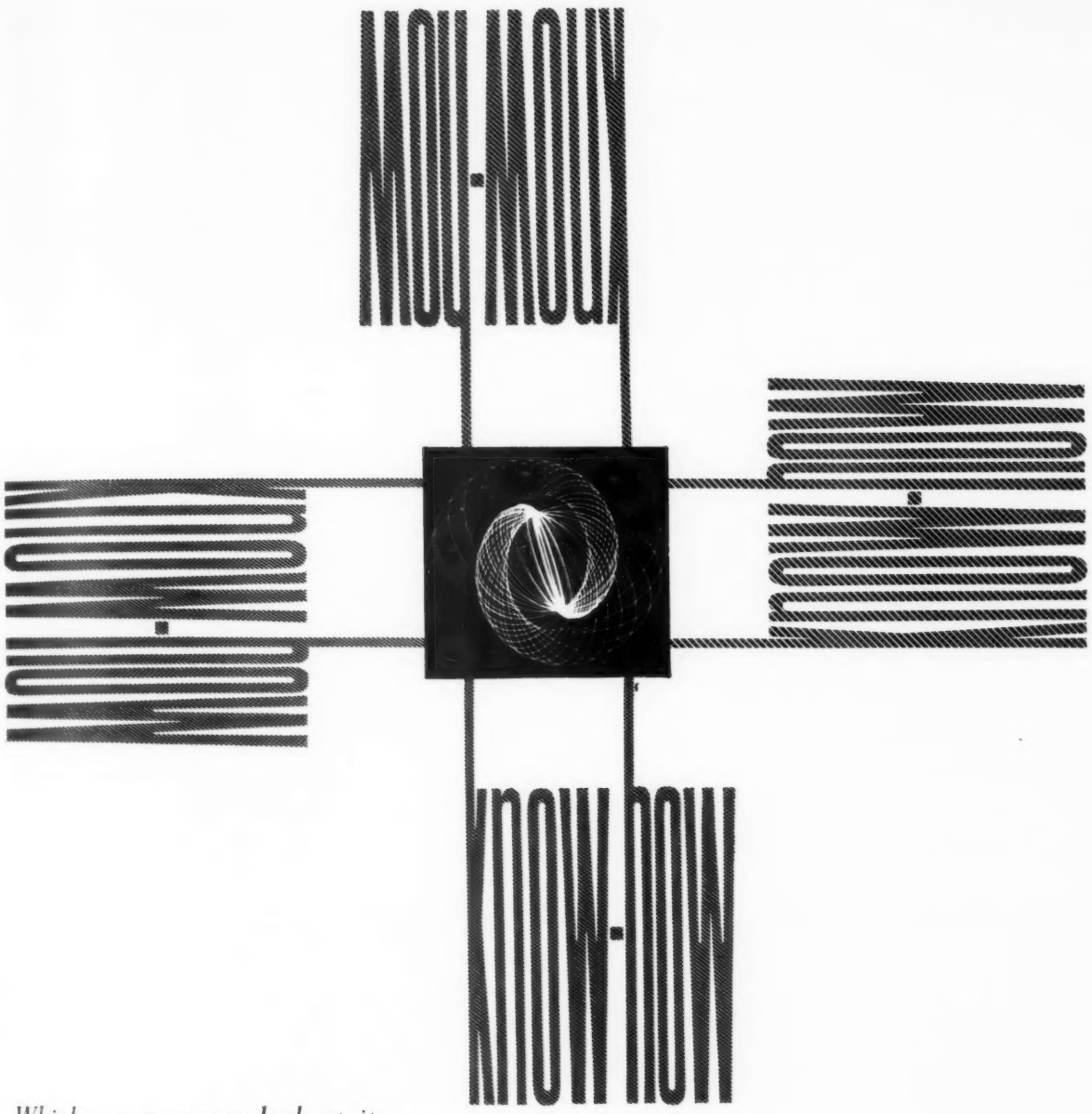
This announcement is issued for and on behalf of

ASSOCIATED LEAD MANUFACTURERS LIMITED,

CLEMENTS HOUSE, 14 GRESHAM STREET, LONDON, E.C.2. CRESCENT HOUSE, NEWCASTLE. LEAD WORKS LANE, CHESTER.

Export Enquiries to: Associated Lead Manufacturers Export Co. Ltd., Clements House, 14 Gresham Street, London, E.C.2

723



Whichever way you look at it . . .

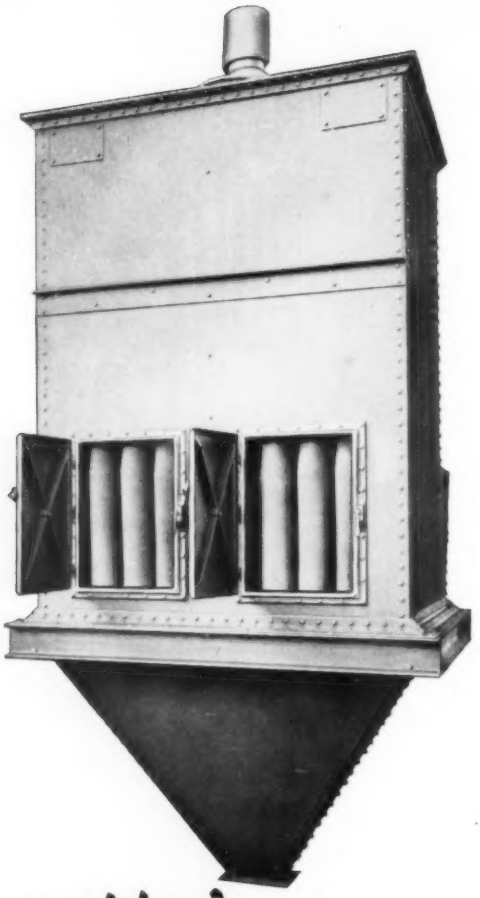
know-how is of primary importance in the manufacturing of Atomic Energy Equipment. This is where Graviner scores, for we can make almost anything in this rather new sphere of activity, whether it be a lead-filled shielded container, a Thulium storage magazine, a magnet for neutron beam focusing or a 20 ton mobile cell unit with viewing windows and handling equipment. We specialise too, in the machining of graphite. Indeed, with the recent addition of 12,500 square feet of factory space we can deal with anything from the making of a tiny graphite spring to a Reflector for a Reactor — all under controlled clean conditions.

If therefore you have a Development or Production problem, our Nuclear Energy Division will be very pleased to help you. Won't you pay a visit to the Gosport Factory and see what we can do ?

GRAVINER *Contractors to The Atomic Energy Authority*

FAREHAM ROAD · GOSPORT · HAMPSHIRE · Telephone Fareham 2511

Also specialists in Airborne, Diesel Engine and Industrial Fire and Explosion Protection, Thermostats and Overheat Switches



The Tornado-Fischer automatic, self-cleaning filter handles continuously, *with negligible maintenance or attention, dust particles of all sizes.*

when the problem's

DUST OR FUMES

turn to 'Tornado'

For over 60 years, Industry has turned to 'Tornado' to settle dust and fume extraction problems. Keith Blackman were the first in the country to use air extraction as the basis for dust and fume exhaust systems. With this record and this experience they are the natural choice for your problem. You too, should 'turn to Tornado' for advice on *complete plants* or individual equipment. There is a qualified representative in every industrial area.

Keith Blackman Ltd

Dust and Fume Control Division

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CLOTH FILTRATION

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Type 270/540 pocket filters

Series TF dust collectors

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WET FILTRATION

Solivore patented wet scrubbers

Hydro precipitator wet washers

CENTRIFUGAL FILTRATION

Cyclogal high efficiency, low resistance cyclones

Cyclogalax 'straight through' cyclones

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PD-KB tubular collectors

ELECTROSTATIC PRECIPITATION

PD-KB electrostatic precipitators

FANS

Paddle type industrial fans

In chemical plant, where fire is a greater hazard today than ever before, the cost of a spark depends upon the efficiency of your fire protection. Through 40 years of fire-fighting experience, Foamite have developed appliances and chemicals to meet the increasing fire risks of industry. Foamite offer you a complete fire-fighting service and a technical staff available for consultation on fire-extinguishing projects of all kinds, anywhere in the world. Foamite protection includes, Carbon Dioxide and specialised Water Spray Installations, Airfoam and Chemical Foam for Tanks and Chemical Plants, fast efficient mechanised appliances and Portable Extinguishers and Chemicals of all types.

Foamite Ltd

FIRE PROTECTION ENGINEERS

Sales Office:
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London N.W.1
and at Plymouth, Devon.
Telephone **EUSton 5578**

FM.12

AIRMEC INSTRUMENTATION

keeps in step with nucleonic needs

MONITORS

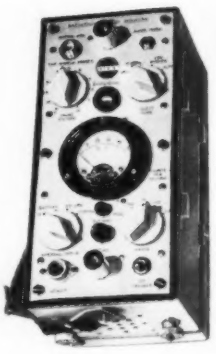
RADIATION MONITOR *Type 1021 B*

- ★ **SAFEGUARDS against contamination.**
- ★ **TRACES radio-active material in chemical analytic processes.**
- ★ **MEASURES contamination of any resulting effluent.**

Designed in conjunction with A.E.R.E. Harwell, this instrument is probably the most widely used general purpose monitor in the world. It has been PROVED by years of user experience to be the most accurate and reliable equipment of its type.

The Radiation Monitor consists of a mains operated Indicator Unit together with a Beta Gamma or Alpha Probe Unit. Indication is provided visually by means of a meter which is calibrated in counts per second, and audibly by means of a loudspeaker. A socket on the front panel is also provided to enable the output to be fed to a scaling unit.

Write for descriptive leaflet No. 26D giving full details.



RADIATION MONITOR *Type 255*

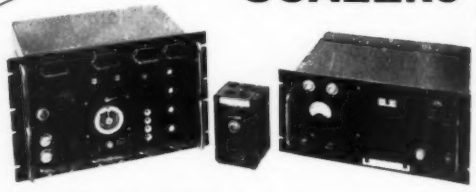
- ★ **Transistorised, battery operated, portable.**
- ★ **Laboratory accuracy under field conditions.**
- ★ **Wide range of probes and accessories available.**

Airmec are proud to be the first to announce a fully transistorised monitor which combines laboratory accuracy with complete portability. The uses include:

1. Checking t e presence and amount of radio-active contamination in laboratories and workshops.
2. Checking atmosphere 'fall-out' and contamination of food, animals, crops, milk and water supplies, etc.
3. Following the progress of radio-active tracer elements in medical, geological, agricultural and industrial processes.
4. Tracing the whereabouts of radio-active areas and making accurate assays of samples in geological surveys.
5. Tracing lost samples of radio-active materials both in buildings and out.

Write for descriptive leaflet No. 177

SCALERS



GENERAL PURPOSE COUNTER *Type 1339 A*

- ★ **Designed and developed in conjunction with U.K.A.E.R.E.**
- ★ **Provides comprehensive scaling facilities for all types of Geiger Scintillation Counters.**
- ★ **Incorporates stabilised E.H.T. supplies.**
- ★ **Fitted with automatic timing control.**

This equipment is built on a unit basis and provides very comprehensive scaling facilities for all types of accurate assay work. It consists of two main units — a Power Unit and a Scaling Unit — together with a number of optional sub-units. These include a Quenching Unit, a High Speed Scaling Unit, an Amplifier/Discriminator Unit, a Paralysis Unit and a Timing Unit.

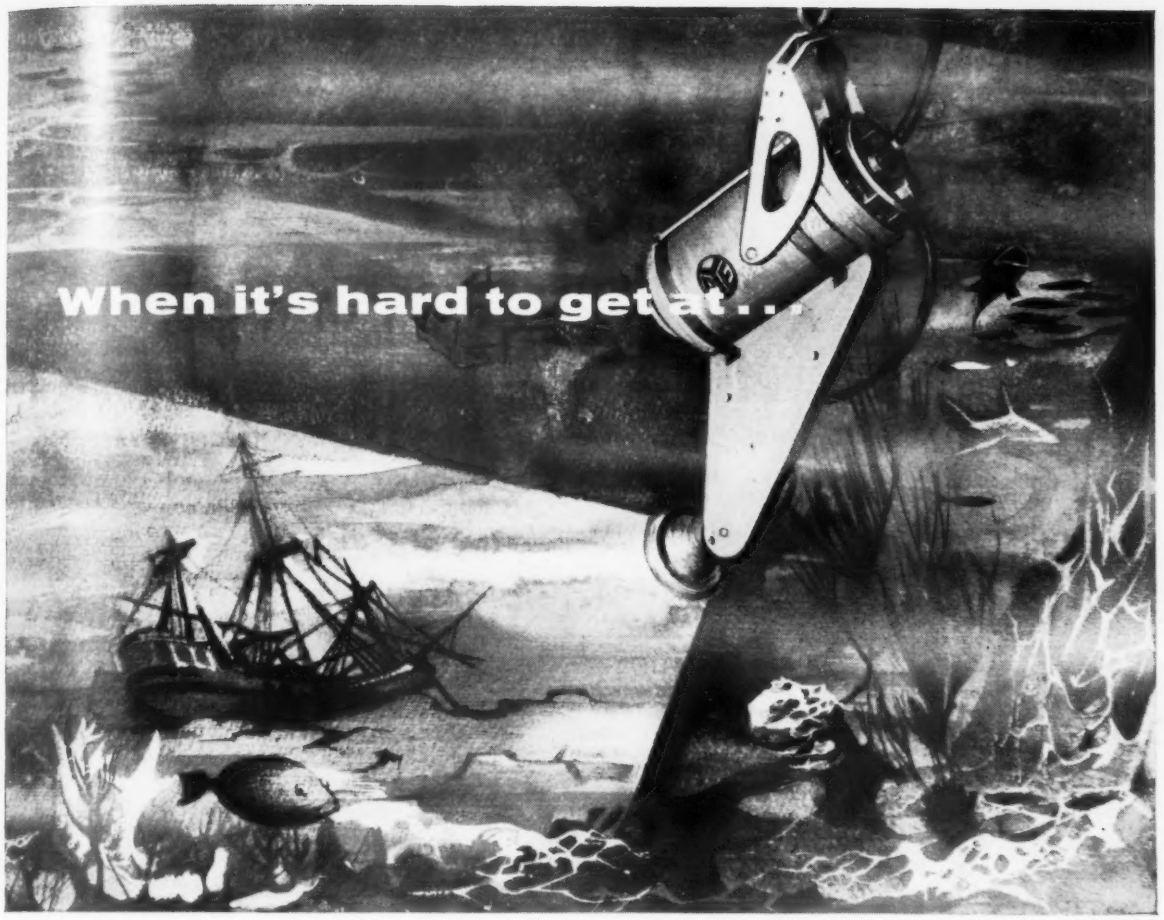
Full details are given in descriptive leaflet No. 185

Airmec

INSTRUMENTS FOR THE NUCLEONIC INDUSTRY

AIRMEC LIMITED · HIGH WYCOMBE BUCKS

Telephone : High Wycombe 2501/7



wise engineers use *Rocol* lubricants

to insure against breakdown and to increase the period between essential maintenance operations on difficult, perhaps dangerous to get at installations where continual maintenance is inconvenient as with sealed underwater T.V. cameras. Plating tough, wear resistant Molybdenum Disulphide—the most advanced lubricant known to engineering science—on to all bearing surfaces, Rocol Molybdenum Disulphide stays in action in conditions of high pressure or extremes of temperature, up to 100,000 lbs. p.s.i. and 1000°F. Find out more about Rocol Lubricants—write for technical details and for advice on your particular problem.

★ *Deep Sea Underwater Television Camera manufactured by PYE LIMITED, CAMBRIDGE, ENGLAND. All working parts lubricated by ROCOL lubricants which are solely recommended.*

USE *Rocol* MOLYBDENISED LUBRICANTS

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ndh 1293xa

Greater safety for hands

With new Shell Dromus Oils

Most modern soluble cutting oils contain phenolic compounds used as coupling agents between the oil and the emulsifier, for better blending and easier mixing. These phenolic compounds can cause skin irritation, especially where modern high-speed machines are used and the emulsion can concentrate, through the evaporation of water, above the safety level.

Shell research chemists have been working on this problem, which has been causing some concern to Management. After considerable research, Shell Dromus Oils have been reformulated and these new cutting oils now produce bland emulsions, which considerably reduce the risk of skin trouble to operators.

The real difficulty was to find a new coupling agent to replace the phenolic compounds, and Shell finally used what their chemists know as a higher fatty alcohol complex. This solved one problem, but presented another. The new coupling agent was volatile at the high temperatures normally used in blending processes. Further research found a solution to this problem by designing and installing new plant.

The new Dromus Oils are every bit as efficient as before and cost no more. They put Management in the welcome position of being able to minimise working hazards at no extra cost. And machine men need no longer be so worried about skin troubles.

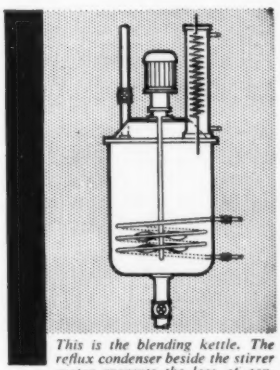
The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organization have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Shell chemists in the U.K., in Holland and in the U.S.A., prepared and examined hundreds of experimental soluble oils, and established that certain combinations of fatty alcohols could be used in place of phenolic compounds with no loss of efficiency. They set to work to discover the best combination and developed a higher fatty alcohol complex which fitted exactly. Then they realised that to blend this new coupling agent into soluble oils would require special plant and new blending techniques.

Exhaustive testing of blend stability, emulsion stability, anti-corrosion and machining properties led to selection of the most promising blends. A pilot plant was set up to produce batches of these for use in field trials.

This field testing and final development proceeded for two years whilst production plants were erected at points so chosen as to give the most economical and rapid delivery throughout the United Kingdom.

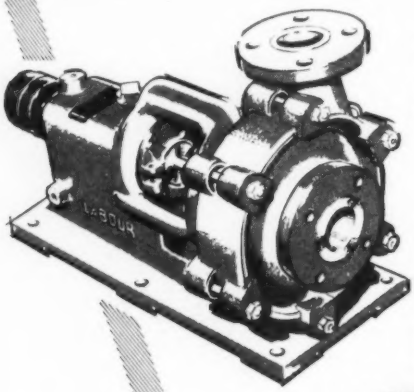


This is the blending kettle. The reflux condenser beside the stirrer motor prevents the loss of constituents volatile at the blending temperature.

NEW SHELL DROMUS SOLUBLE CUTTING OILS

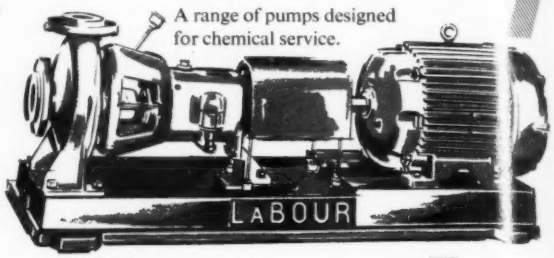
another proof of Shell leadership in lubrication

Tick **No 25** on reply card for further details

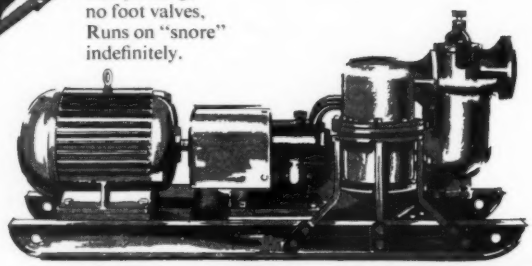


A rubber lined pump for handling hydrochloric acid, ferric chloride solutions, etc.

A range of pumps designed for chemical service.



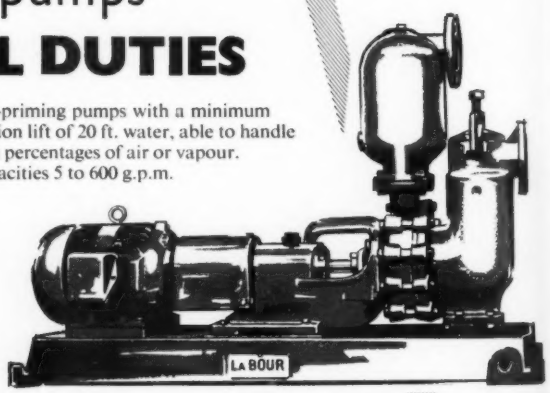
Specifically developed for mines. Operates in confined spaces. Self-priming, no foot valves, Runs on "snore" indefinitely.



LABOUR

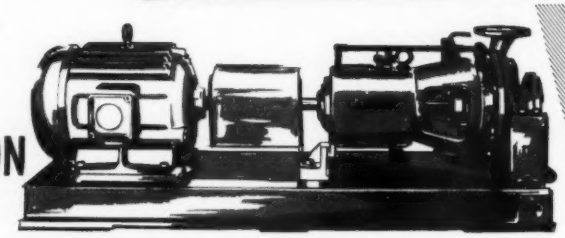
have the pumps for SPECIAL DUTIES

Self-priming pumps with a minimum suction lift of 20 ft. water, able to handle high percentages of air or vapour. Capacities 5 to 600 g.p.m.



For vacuum extraction duties and use with filters, condenser installations, etc. Will extract liquor from vessels under a 28 inch vacuum.

NO CORROSION



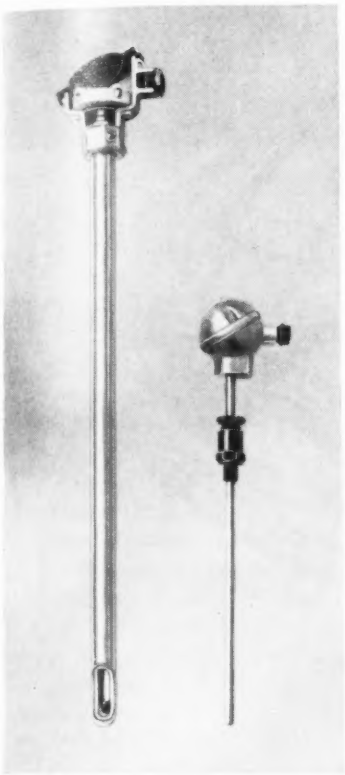
Process pumps for handling hot liquids. Heads up to 300 ft., capacities up to 1000 g.p.m.

LABOUR

BRITISH LABOUR PUMP CO LTD

BLUNDELL ST LONDON N7 ***Tel: North 6601-5 Grams: Laboupump London***

Temperature Detection



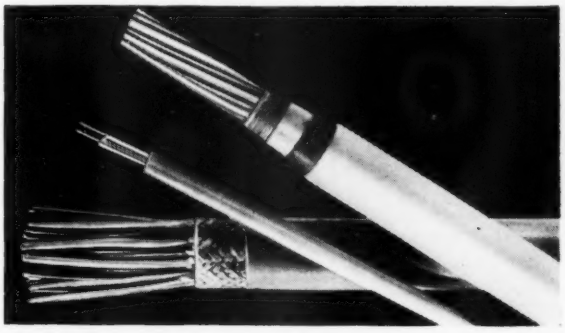
Degussa Thermocouple Assemblies

suitable for continuous working under varied conditions and temperatures up to 1800°C. Bare Thermocouple Wire matched to very fine tolerances can also be supplied. Special requirements considered.

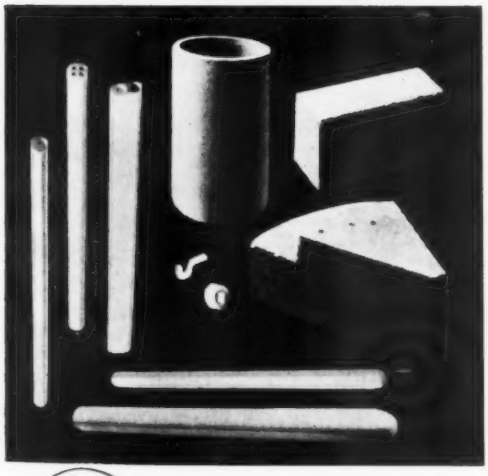
DEGUSSA HANAU

Degussa Compensating Leads

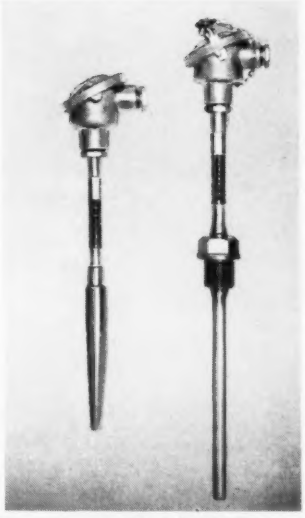
as bare wires or with various coverings. Solid or stranded conductors; single, double or multicore cables, according to requirements.



Degussit Oxide Ceramic Products



for the highest thermal chemical, mechanical and electrical requirements in sintered dense alumina, ruby, spinel, zirconia and (porous) magnesia and kaolin bonded corundum. Tubes for gas withdrawal, furnace construction and protecting thermocouples. Construction parts, cements, insulating materials for high temperature furnaces. Lilliput furnaces, up to 2000° C. Crucibles and other high temperature equipment.



Degussa Resistance Thermometers

for industrial or laboratory uses. Elements only supplied, or complete assemblies suitable for the most arduous conditions. Temperature range —200°C to +850°C. Special requirements considered.

DEGUSSIT

ON SHOW AT **STAND M 561**

I.E.A. EXHIBITION, OLYMPIA MAY 23-28

BUSH BEACH & SEGNER BAYLEY LTD.,

St. James' House, 44, Brazennose Street, Manchester, 2. Tel: Deansgate 5134-8 Telex: Chemicals, Mchr. 66180

TA 3825

Ornate stirrup with arab-sque design—typical of sixteenth cen-ry German workmanship.

Something special...

The finished product reflects a skill and an intimate knowledge of his materials which justify the pride of the craftsman. Here at Consett we are proud of our long-standing reputation for the production of fine quality mild steel—proud too of the recognition earned for the development of special quality steels for particular applications. We have recently produced a most interesting and informative booklet—"Steels for the Job"—which we think you should read. May we send you a copy?

STEEL FROM CONSETT

CONSETT IRON COMPANY LIMITED · CONSETT · CO. DURHAM
Telephone: Consett 341 (12 lines) Telegrams: Steel Phone Consett

Our Technical and Research Department will also welcome enquiries from any whose problem is . . . . STEEL

Gas bearing pumps— totally enclosed, gas lubricated—for liquids up to 700° C, without contamination . . .

. . . ANOTHER ENGINEERING ADVANCE BY BRISTOL SIDDELEY

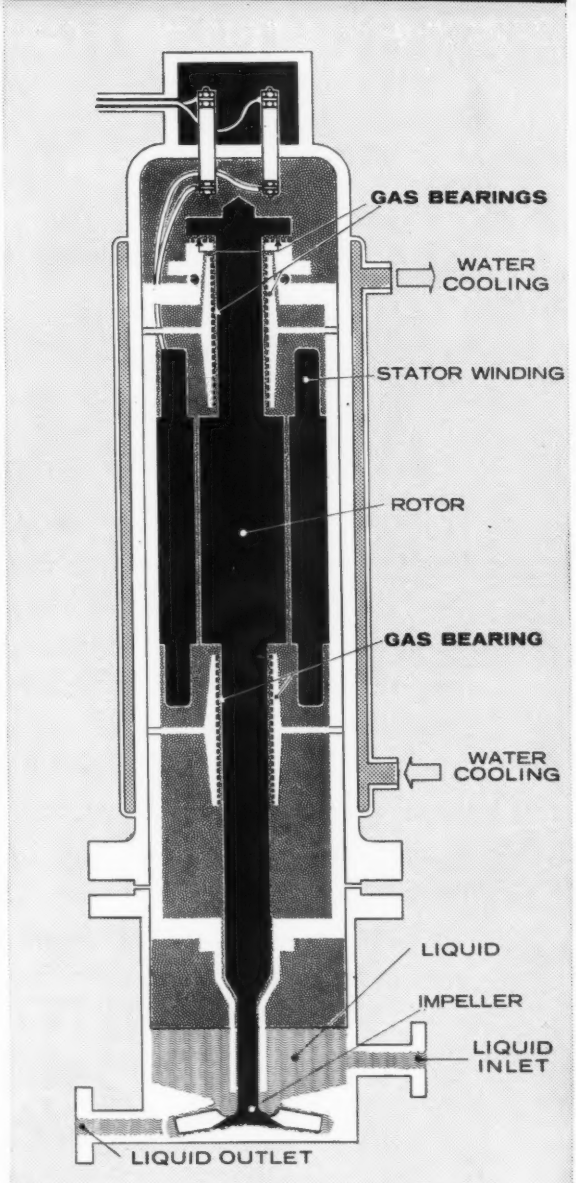
One of the largest manufacturers of motive power units in the world, Bristol Siddeley Engines Limited produce gas bearing pumps. The range covers a wide performance capacity and will pump liquids up to 700° C with a power input from fractional to 30 hp.

Bristol Siddeley gas bearing pumps have been designed specifically for systems where the contamination of liquids by lubricants or the atmosphere cannot be tolerated. Each unit, fitted with self-acting gas bearings, is totally enclosed and no seals are required between the impeller and the bearings.

Gas bearings have several great advantages over oil lubricated bearings: the load-carrying capacity increases with speed, temperature and pressure; the bearings are supported on a film of chemically pure gas contained within the system, so there is no metal-to-metal contact under operating conditions, and wear and maintenance are reduced to an absolute minimum.

Widest experience—greatest range

Bristol Siddeley gas bearings were developed originally to meet the extremely fine limits of operating purity and precision of nuclear engineering. But gas bearings have many other applications where a rotating shaft must be supported in such a way that no contamination and leakage can be allowed and where the supply of chemically pure fluids or gases is essential: in the textile, chemical engineering, pharmaceutical, food storage and processing industries, to name but a few. Bristol Siddeley produce a wider range of gas bearings than any other manufacturer and have the greatest experience in their design and application.



For further information about Bristol Siddeley gas bearing pumps and gas compressors, please write to H. J. Prince, Sales Manager, Reactor Components Division, Bristol Siddeley Engines Limited, PO Box 17 Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED

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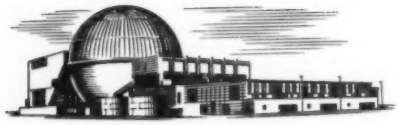
BY APPOINTMENT TO HER MAJESTY THE QUEEN
Suppliers of Fire Extinguishers *The Pyrene Company Limited*

facing new industrial fire problems



The Pyrene Company, with its unrivalled facilities for research, keeps ahead of changing industrial techniques, and is constantly developing the means to overcome the new fire risks they involve. As makers of the world's most comprehensive range of fire-fighting equipment, The Pyrene Company can give you invaluable and impartial advice on any fire protection problem—it is yours for the asking. We are proud to have given advice on fire protection—and supplied major fire-fighting equipment—for most British atomic centres already constructed. This service is also being applied to many new engineering plants and production methods used in modern industry. Consult Pyrene Fire Engineers and ensure maximum fire protection for valuable plant and human lives too.

Pyrene TRADE MARK FIRE APPLIANCES

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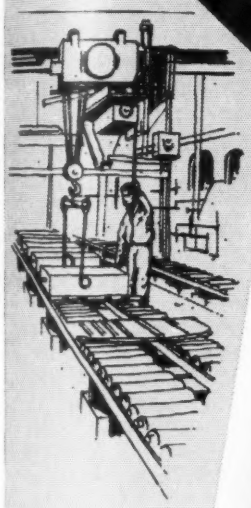
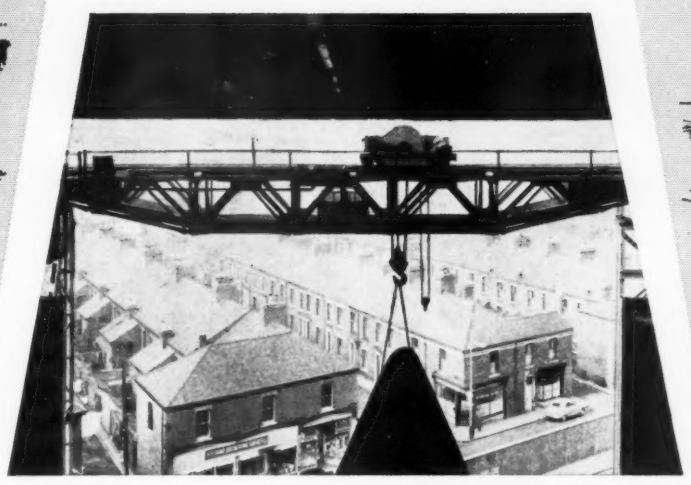
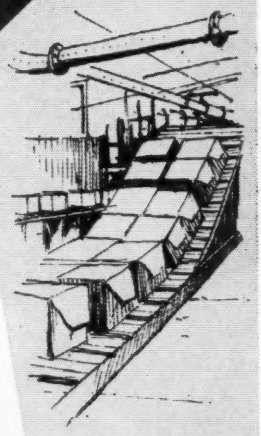
PATERSON HUGHES
ENGINEERING COMPANY LIMITED





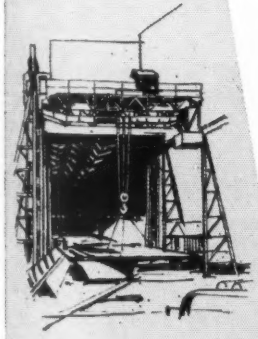


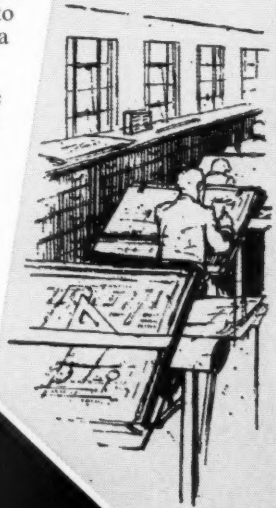
A Paterson Hughes 30-ton electric overhead travelling crane at Blyth Dry Dock and Shipbuilding Co. Ltd.—by whose courtesy this photograph is reproduced.

Paterson Hughes cranes are built in their modern crane shop in Scotland to designs based on their 35 years of experience in this field.

If the Paterson Hughes range—from hand jibs to 100-ton overhead cranes—does not include a standard model suited to your exact needs, then a special will be designed at a competitive price.

Paterson Hughes engineers will also design complete crane systems, extending from your goods inwards bay to the finished products warehouse, bearing in mind the special requirements of each industry.





THE PATERSON HUGHES

CRANE DIVISION

Specialists in modern crane practice

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Wyndford Works
Maryhill Glasgow
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P.2114

give NEWTHERM your toughest insulation assignment

Newalls (Reg'd Brand) NEWTHERM Calcium Silicate insulation is the finest answer yet to many of industry's heat insulation problems. *Strong and rigid,* Newtherm withstands rough handling in transit and erection, with negligible breakages even during transport to remote sites. *Exceptionally light,* Newtherm can be applied in difficult situations with ease — even the largest sections being manageable in one hand. *Moisture resistant,* Newtherm retains much of its strength even when immersed in water, does not deform, and quickly dries, leaving its strength and thermal efficiency unimpaired. *Easily applied,* Newtherm offers a smooth surface and straight edges for speedy fitting, and is available in many standard sizes for immediate application.

NEWTHERM Calcium Silicate is manufactured solely by

NEWALLS INSULATION COMPANY LIMITED

Head Office : **WASHINGTON, CO. DURHAM, ENGLAND**

A member of the TURNER & NEWALL ORGANISATION

Offices and Depots at :

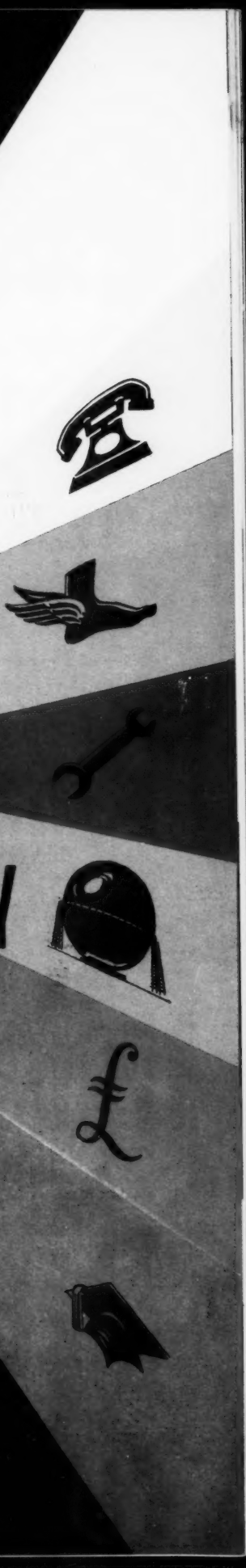
LONDON, GLASGOW, MANCHESTER, NEWCASTLE UPON TYNE, BIRMINGHAM, BELFAST, DUBLIN, BRISTOL and CARDIFF.

Agents and vendors in most markets abroad.

SOLARTRON

common stimulus to progress

IN EVERY INDUSTRY



Overleaf we show, in easy reference form, the stimulus which Solartron is giving to every field of human endeavour today. This can only be a brief outline—but the responsible businessman owes it to himself to be well-informed on the exciting potential of electronics, the accelerator of progress. Each step forward in electronic technique or application sparks off a chain reaction of inventiveness and progress in every industry.

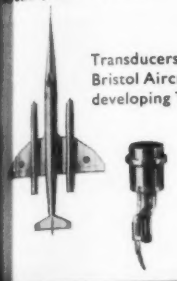
SOLARTRON

Learn here how Solartron is accelerating progress, cutting costs and solving problems in your *field!*

	INSTRUMENTS	COMPUTERS
	A complete range of precision measuring instruments, oscilloscopes for every application; dynamic analysis equipment; digital display instruments and both conventional and transistorised power supplies.	***Advanced modular construction 'Solartron' series computers ranging from the Solartron Simplifier Analogue Tutor, through 'Mini-Space' and 'Space 30' to 'Space 60', 'Mercury' and larger special-purpose machines.***
COMMUNICATIONS	**Telecommunications Radio Television Facsimile Teleprinting Radar & Sonar**	Line and radio link power measurement; a.f., and r.f. amplifier testing; precise calibration; vectorial measurement and oscillographic, metered or digital display; microwave test and power supply instrumentation.	Synthesis and evaluation of networks; repetitive test of simulated systems under programmed conditions; design evaluation of overhead transmission equipment; solution of dynamic transient loading problems.
AUTOMOTIVE & TRANSPORT	**Aviation Railways Shipping Roads Spacecraft**	Vibration analysis and display; evaluation of aircraft and automotive servo systems; testing of mobile electronic equipment; design and development of power controls, instrumentation of research vehicles and guided weapons.	Servo system, suspension and power transfer system simulation and evaluation. Solution of aerodynamic, hydrodynamic and allied linear and non-linear problems of advanced nature. Investigation of fuel or gas flow and throttling in jet and turbine engines.
MATERIALS & MANUFACTURE	**Raw Materials Chemicals Minerals Mass Production Iron & Steel Textiles Food & Drink**	Full range of precision electronic instruments for all aspects of measurement in industrial research, development and production test. Choice of high-accuracy meter, oscilloscope or digital display presentation.	Process control simulation and analysis, analogue synthesis of types of controlled power equipment—paper, textile, movement, etc. Chemical plant and refinery design, evaluation of complex
POWER	**Nuclear Water Electricity Gas Steam Solar IC Engine Gas Turbine**	Instrumentation for supply testing and visual display. Stabilised conversion (AC-DC), and battery replacement (transistorised) bench units and sub-units. Vectorial measurement and analysis equipment. Test instruments for gyros, synchros, and servo-mechanisms.	Simulation of nuclear reactor controllers and basic reactor processes. Investigation of reactor thermodynamics and kinetics. Determination of critical and runaway conditions. Synthesis of power transmission networks.
COMMERCE	**Insurance Banking Credit Control Stock Control Warehousing Packaging Retailing**		Derivation of future national and international business trends by analogue simulation based on known information and [illegible] economic inter-relationships.
RESEARCH & EDUCATION	**Services Technical Training & Education Schools & Universities Institutions Public Authorities Hospitals & Medical Science**	For use in technical colleges and universities—oscilloscopes, measuring instruments and power supplies of highest quality. Reliable, ruggedly constructed, functionally designed and utilising the most up-to-date design techniques.	Simple computers, designed specifically for training purposes, solution of differential equations and basic dynamic problems, invaluable also for training operators of larger and more complex machines.

DATA HANDLING

...cision, ultra-high temperature pressure ...nsducers; data logging, conversion, dis... ...y and high-speed print-out equipment; ...ustrial multi-channel magnetic tape re... ...der reproducer systems.



Transducers used by Bristol Aircraft in developing T.188

Data logging from test rigs of multiple variable parameters; high accuracy magnetic recording of local or telemetered data from aircraft or missiles; strain and pressure measurement instrumentation; high-speed digital recording from test rigs and prototypes.

Precise measurement of pressures under exceptional conditions. Monitoring, logging and analogue or digital recording of process data for every industry. Programmed control of plant and processes by magnetic tape and associated error-sensing equipment.

Continuous monitoring of supplies—electricity, water, gas, compressed air, etc. Digital logging for permanent record, digital display for remote supervision and control. Precise pressure measurement under extreme conditions.

DATATAPE

OSCILLOSCOPES

RADAR Simulation

Training, tactical and special-purpose evaluatory radar simulators having the highest degree of display authenticity. For advanced training in, and appreciation of, military, naval, A.T.C., or marine navigation radars.

Air traffic control training and evaluation of new systems, training of air force, naval and merchant marine radar operators and controllers. Tactical training in manoeuvre or combat-air, sea, or combined operations.

RADAR SIMULATOR

CYBERNETICS

Simulation means more concentrated training, more effective training—in radar appreciation, for control, navigation or defence. Simulated radar data can be fed to early warning systems to give vital recognition practice and heighten awareness under emergency conditions.

BUSINESS Machines

ERA, Electronic Reading Automaton, reading business information directly from original documents. Cybernetic-principle machines for accelerated training in manual co-ordination processes.

Accelerated training of morse, teleprinter, Teletypesetter and other operators by cybernetic training machines. High-speed recognition of printed data for transmission serially in any form over existing telecommunication or radio links.

Reading of p.s.v. ticket tally rolls for central data processing, providing traffic analyses and cash return information to operators in a fraction of the time previously required.

E.R.A.

High-speed reading of tally rolls from public utility meter readers —gas, electricity, water. Provides more immediate and concentrated record for accounts and control needs, direct input information for computer assimilation.

High-speed serial reading of printed or typewritten characters for computer input use. In banks, insurance companies, Co-ops., Govt. departments, public utilities and all large organizations handling continuous-feed or separate document information sources.

Training for complex muscle-eye co-ordination tasks achieved immeasurably more quickly and effectively than by human instruction. Unsuitable pupils quickly assessed thus improving training economy factor.

AUTOMATION & Process Control

X-Ray Spectrometer—for continuous, accurate non-destructive analysis; Electronic Checkweigher for precise packaging control; programmed actuators; automatic warehousing order-filling equipment.

X-RAY SPECTROMETER

Control of transport fleet overhaul schedules by routine spectrometric analysis of IC engine oil, thus assessing accurately the wear of bores and bearings.

Continuous analysis and control by X-ray spectrometry down to Atomic No. 12—non-destructive, high-accuracy. High-speed electronic checkweighing of finished or cast parts integral with inspection processing.

SOLARTRON

High-speed electronic weighing of packaged foods, etc., at rates of up to two per second; automatic warehousing for institutional, wholesale or retail application—input demand renders listed items available inside fifteen seconds.

CHECKWEIGHERS

SYSTEMS CAPABILITY

...what SOLARTRON can do

It must be apparent from the pattern of the preceding pages that Solartron product lines are inter-related and complementary in application.

Continuous research and applications engineering in all these fields gives Solartron, now, a unique insight into present-day and future requirements of industry, resulting in a really soundly based *systems* capability—ability of the highest order to judge and advise in terms of tomorrow, to see the whole picture and do the whole job.

WHAT A 'SYSTEM' DOES

A 'system' is a purposive interconnection of electronic and other units, working together to solve a problem or to effect precise control in a specified way. Parts of an electronic system are concerned with measurement, others record, compute or compare. There may be—as in a controller which optimises a process—no visible output; or, for another application, measurements may be printed-out at a hundred a second. However the job is done, electronics gives you closer control, faster presentation of information, points up trends—gives timely warning of deviations. In the sphere of training, electronics is essentially impartial, flexible—a dozen blocks ahead of human teaching; for communicating information electronic techniques are instant and error-free. Learn how your industry can use electronics—ask Solartron.

CLOSING THE GAPS

Solartron, in addition to continuously programming expansion in the field of precision measurement and display, have repeatedly 'broken through' in research; in 'ERA', to clear the bottleneck at digital computer inputs; in 'SAKI', which uses advanced cybernetic principles to speed operator training—plus a host of advances in magnetic recording, analogue-to-digital conversion and very-low-frequency dynamic analysis. Tiny pick-offs which faithfully transmit intelligence under extreme conditions are in production at Farnborough by methods which give new meaning to the word precision. Radar simulators, automatic X-ray analysers, high-speed printers and a new generation of 'learning' machines too, are in production in this ultra modern manufacturing plant.

Whatever the skills and types of 'know-how' needed to find the best solution to a systems problem, benefit from continuous cross-fertilisation of ideas—talk to Solartron experts in O & M, data processing, mass manufacture and process control, automation, computing, simulation or training. Then let us advise you, whatever your industry, on the best solution to the measurement and control problems you see ahead.

enquiries should be addressed to THE SOLARTRON ELECTRONIC GROUP LIMITED

Victoria Road, Farnborough, Hampshire. Telephone: Farnborough (Hants) 3000

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THE SOLARTRON ELECTRONIC GROUP LIMITED

45 Thames Street, Kingston-on-Thames, Surrey

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Position Held .....

Company *(Name and Address)* .....

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.....

Instruments 1	Oscilloscopes 2	Power Supplies 3	Dynamic Analysis 4
Digital Recorders 5	Computers 6	Data Handling 7	Radar Simulators 8
Reactor Simulators 9	X-ray Spectrometers 10	Checkweighers 11	Automatic Warehousing 12
ERA 13	Cybernetics 14	Automation 15	Process Control 16

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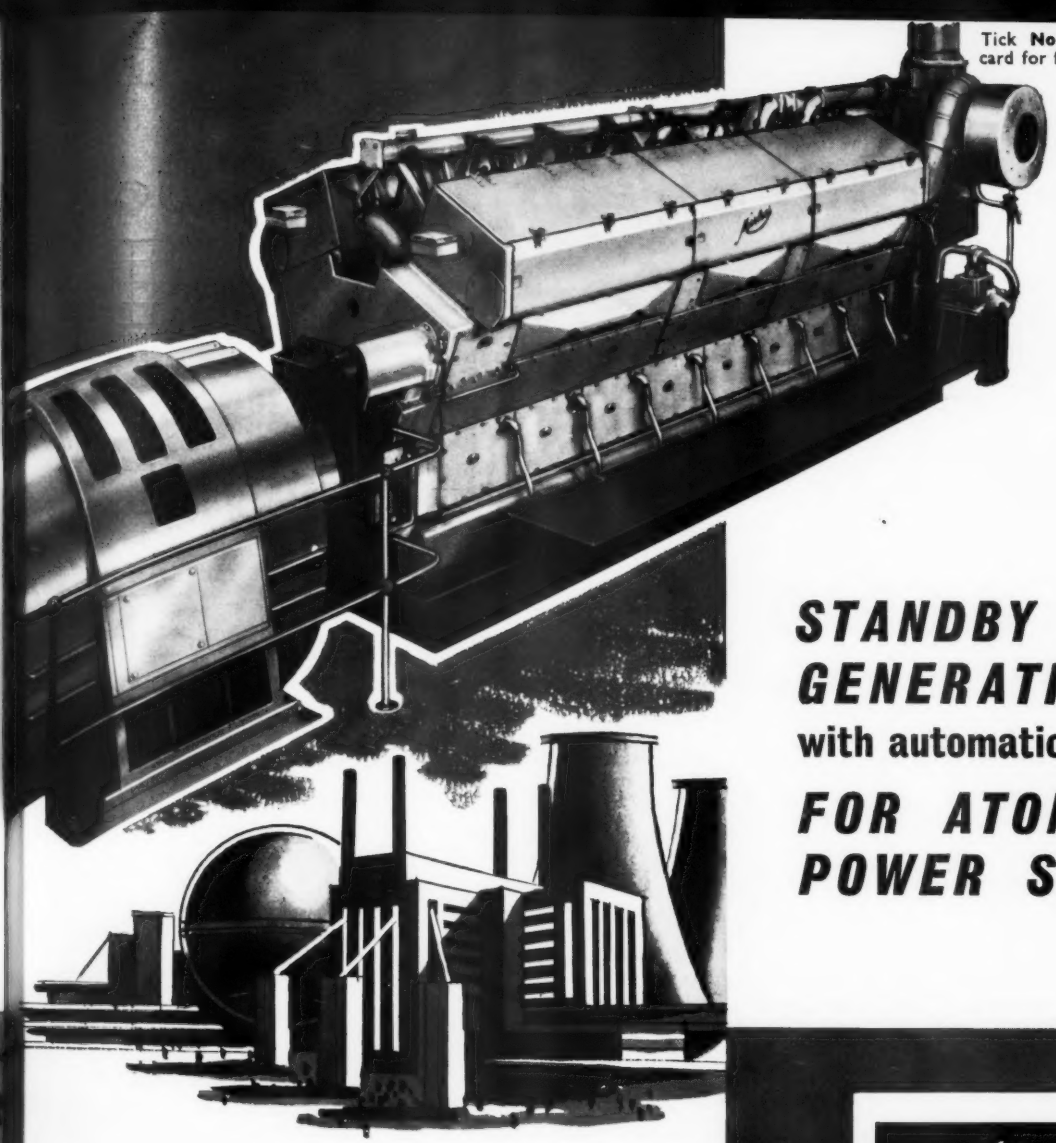

STANDBY GENERATING SETS
with automatic starting
FOR ATOMIC POWER STATIONS

Within a few seconds of receiving the starting signal and without manual attendance, these Mirrlees oil-engine sets will carry full load, providing a reliable auxiliary and standby supply for atomic power stations and other installations where it is essential to forestall breakdowns and serious loss due to cessation of mains power supply. The Mirrlees J and JV Types of engine cover a comprehensive series including 3, 4, 5, 6 and 8-cylinder in-line engines and 12 and 16-cylinder vee-form engines. All can be offered in naturally aspirated or turbocharged form, the latter with or without air aftercoolers.

Mirrlees diesels

The power range extends from the 210 BHP J3 three-cylinder naturally aspirated up to the 2272 BHP JVSS 16 sixteen-cylinder turbocharged engine with air aftercooler.

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HAZEL GROVE · STOCKPORT · CHESHIRE

A member of the HAWKER-SIDDELEY Group

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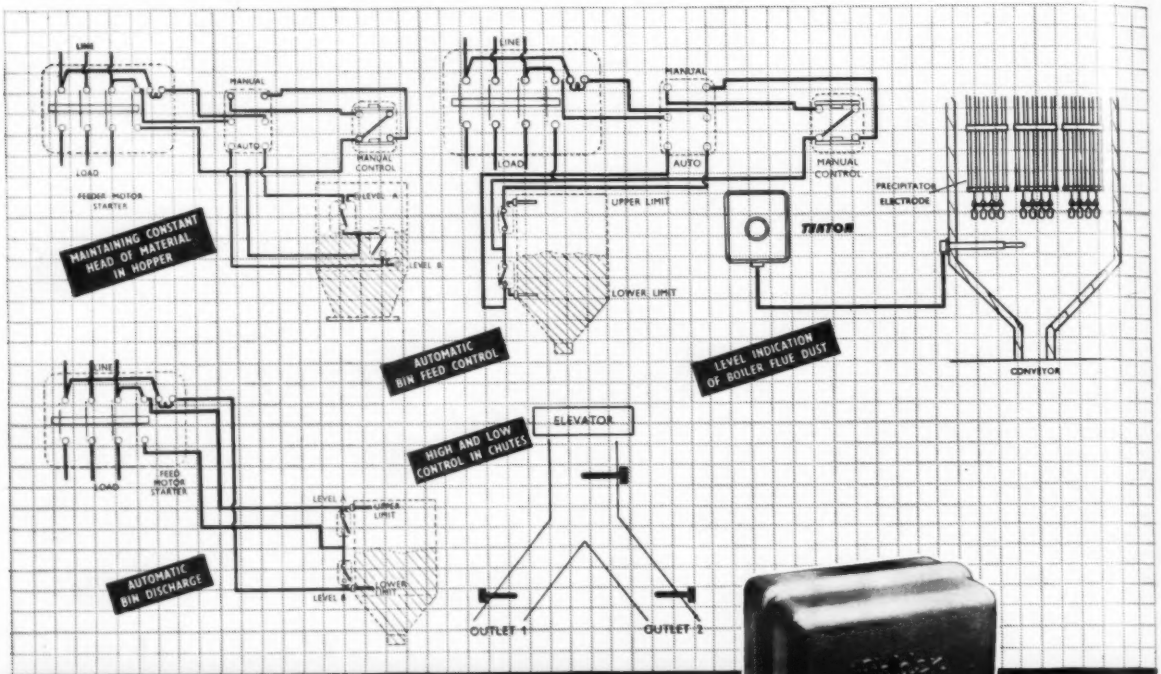
level control and indication



by the Fielden CAPACITANCE METHOD

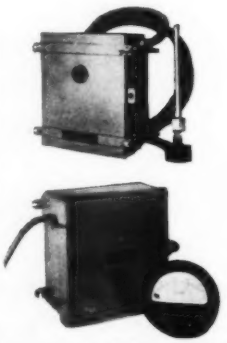
The principle of capacitance control and indication of level for industrial purposes has been successfully used by Fielden Electronics Ltd. for the past ten years. In that time it has produced a range of instruments used throughout the world to answer almost every level problem involving any liquid or free-flowing solid regardless of conductivity, insulating value, density or corrosive properties. Installation is simple, there are no moving parts in the container and direct contact with the material is unnecessary.

Send for fully illustrated leaflet GL1/NP

The range includes the famous

TEKTOR REGD. LEVEL CONTROLLER

TELSTOR REGD. LEVEL INDICATOR



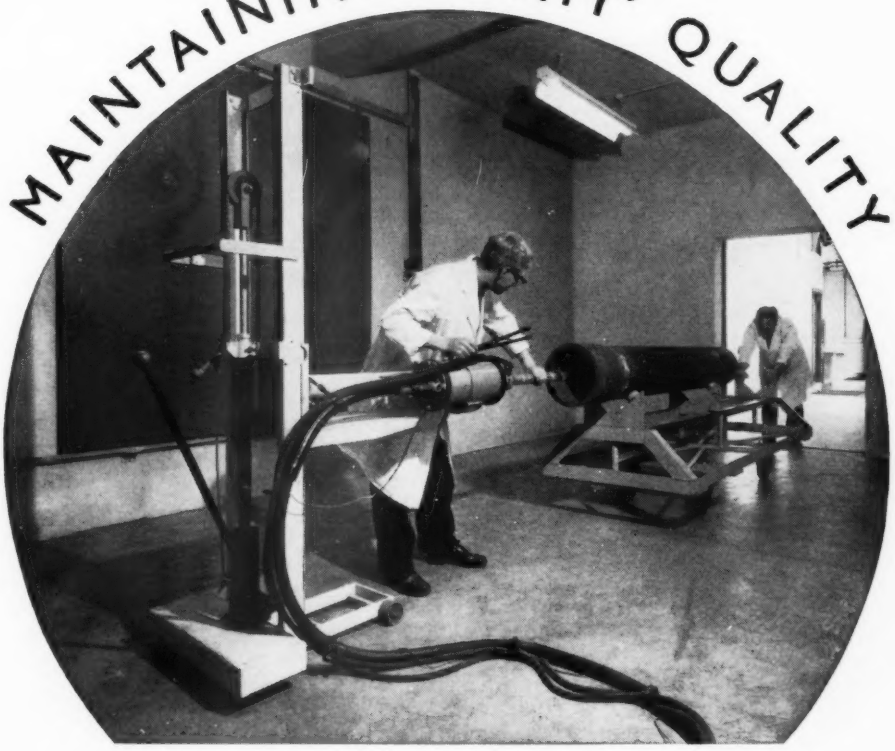
solids or fluids their levels can be accurately measured by the Fielden method

Fielden

FIELDEN ELECTRONICS LTD · WYTHENSHAWE · MANCHESTER Phone: Wythenshawe 3251 (4 lines) Grams: Humidity Manchester
ALSO AUSTRALIA, ITALY AND CANADA *Branch Offices:* LONDON, WALSALL, STOCKTON-ON-TEES, EDINBURGH AND DUBLIN.
Agents throughout the world
TT3

Indicating Recording Control

MAINTAINING 'UNIT' QUALITY



OUR welded tubular vessels, heat exchangers and other pipework, many of which operate at high pressure, demand the maximum standards of safety. We accordingly make use of specialized equipment for non-destructive testing which includes the most up-to-date X-ray installations — specially designed for the radiography of reactor stand pipes as seen in the illustration.

A rapid examination of the butt-welds of these tubes is made possible by the use of the 150 kV Mueller extended anode X-ray set marketed by Research and Control Instruments Ltd., who also designed the necessary protection. Since this unit radiates through 360° it has to be shielded by the use of a concrete cell with lead lined interlocking doors through which the tubes are wheeled. On this particular application this X-ray technique gives an average production sensitivity of about 0·06%.

Our radiographic department was specially designed to give a fast turn-round of welds and it is an important link in the works production system. Adjacent to the 150 kV cell is a Mueller 300 kV conventional anode unit which is used for any welds which cannot be reached by the extended anode.

The common range of radio isotopes is available for use in a special compound. An ultrasonic testing section is also maintained to ensure that the full range of non-destructive testing aids is ready for immediate use for any particular problem.

THE UNIT SUPERHEATER UNIT AND PIPE COMPANY LTD

UNIT WORKS, SWANSEA · *Telephone:* SWANSEA **54091** (*6 lines*) · *Telegrams:* 'SUPERUNITS', SWANSEA · *Telex:* **4835**

THIS
is just typical

Typical of the kind of work in which Marston's excel. It's a 7,000 gallon light alloy tank* for demineralised water, in course of construction — one of the many fabrications of varying shapes and sizes entrusted to Marston's by all kinds of industries. If you're contemplating engineering, chemical, petroleum or nuclear power plant that calls for components to unusual specifications, consult us at the design stage: our experts can contribute much to the smooth, speedy and economical execution of your plans.

Process plant · Bursting discs
Pressure vessels · Heat-exchangers
Pipework·Special-purposemachines
in aluminium, titanium and other non-ferrous metals.

*Made to the order of Matthew Hall & Co. Ltd.

ICI

MARSTON EXCELSIOR LIMITED
A subsidiary of Imperial Chemical Industries Limited
Fordhouses, Wolverhampton

MAR.277

Critical inspection at economic speeds

THE FUEL ELEMENT DESIGN of the nuclear power station at Berkeley includes a sub-assembly of two graphite struts joined by a short zirconium alloy cross-member. The ends of the struts are rebated to accept the cross-member and drilled to contain a metal fixing pin, and are also grooved to a pattern which enables them to accommodate the fins of the uranium fuel-element cans.

Extreme care in the machining and handling of these struts is essential. Moreover there must not be the slightest flaw to cause trouble either during the insertion of the struts into the reactor core or when the reactor is on power. The closest examination of every part of every graphite strut is vital. Radiographs are taken at two points, one 90° to the other.

At the Powell Duffryn Carbon Products works at Hayes the X-ray inspection unit is an integral part of the assembly line. The struts must never leave the "clean conditions" Nuclear graphite machine shop from the time basic raw graphite stock is received to the time the finished strut is packed for despatch to the Fuel Element Assembly Department of the Atomic Energy Authority. The X-ray unit, therefore, has to keep pace with the special machines on which the struts are cut and shaped. This means that paired radiographs of each strut must be produced at a rate of at least a pair every thirty seconds during the working day.

For this vital inspection work Powell Duffryn use 'Crystallex' X-ray Film size 24 × 24 inches.*

Kodak

'CRYSTALLEX' X-RAY FILM

for really critical examination at economic speeds

** This size is available to special order.*

'Kodak' and 'Crystallex' are trade-marks

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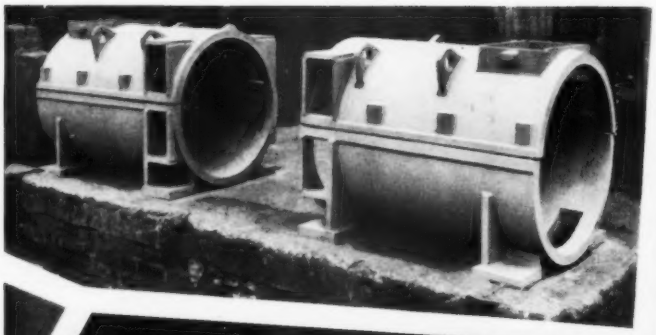
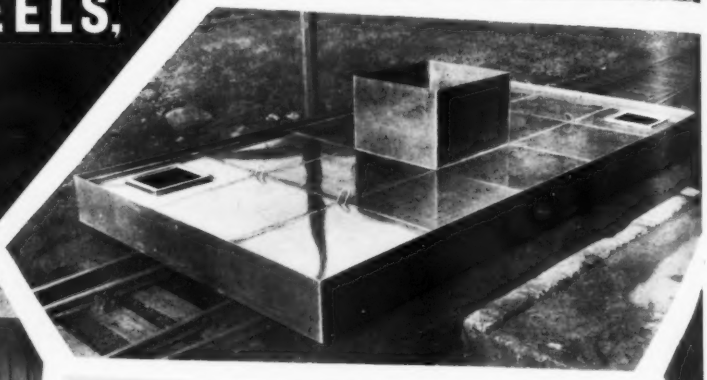


For General Fabrication in MILD STEELS, STAINLESS STEELS, and ALUMINIUM ALLOYS



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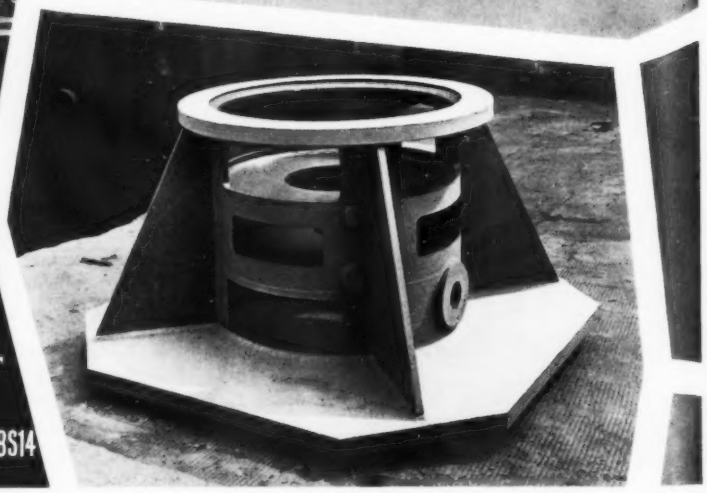

WE ALSO SPECIALISE IN DISHED AND FLANGED ENDS
MAX. DIA. 24" MAX. THICKNESS 1/2"
Made to suit Customer's inspection requirements from BS14

A Vital contribution to Atomic Power . . .

"WANDLESIDE"

ARMOURED CABLE

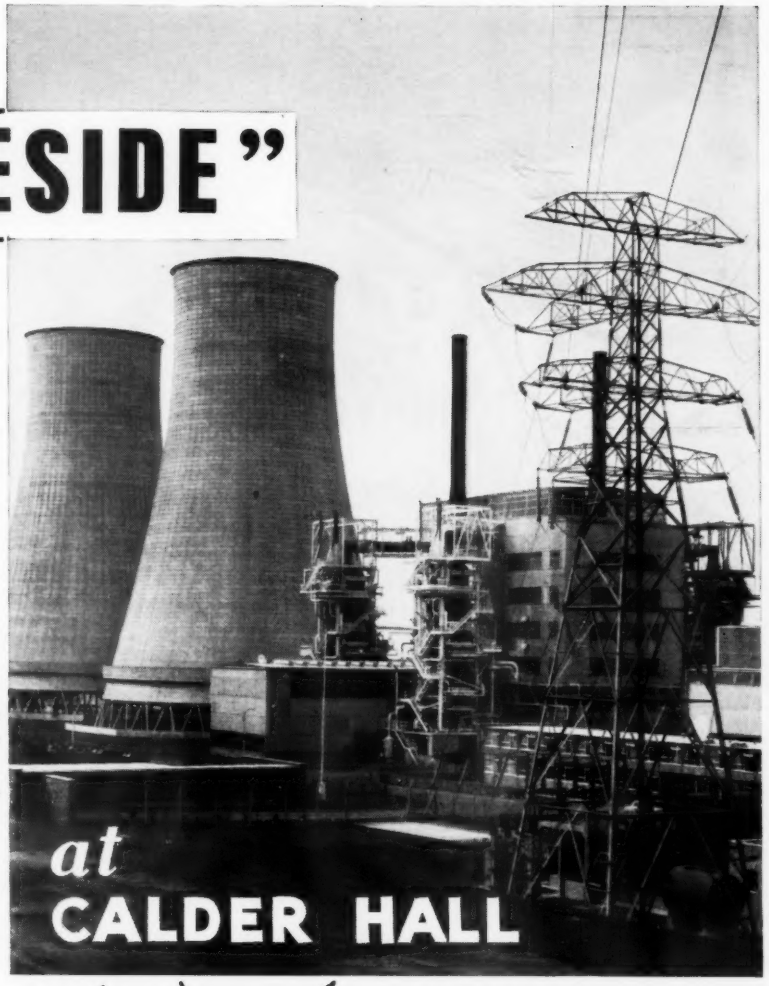

Photo by courtesy U.K. Atomic Energy Authority

With the advancement of Atomic Power, cables must play an important part in the efficiency and reliability in the production of Nuclear Energy. Only the best is good enough and Wandleside Cables are eminently suitable.

WANDLESIDE CABLES *for Nuclear Energy*

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One of FALKS Group *Telephone: VANdyke 7544 (5 lines)* *Telegrams: Wandleside, London*

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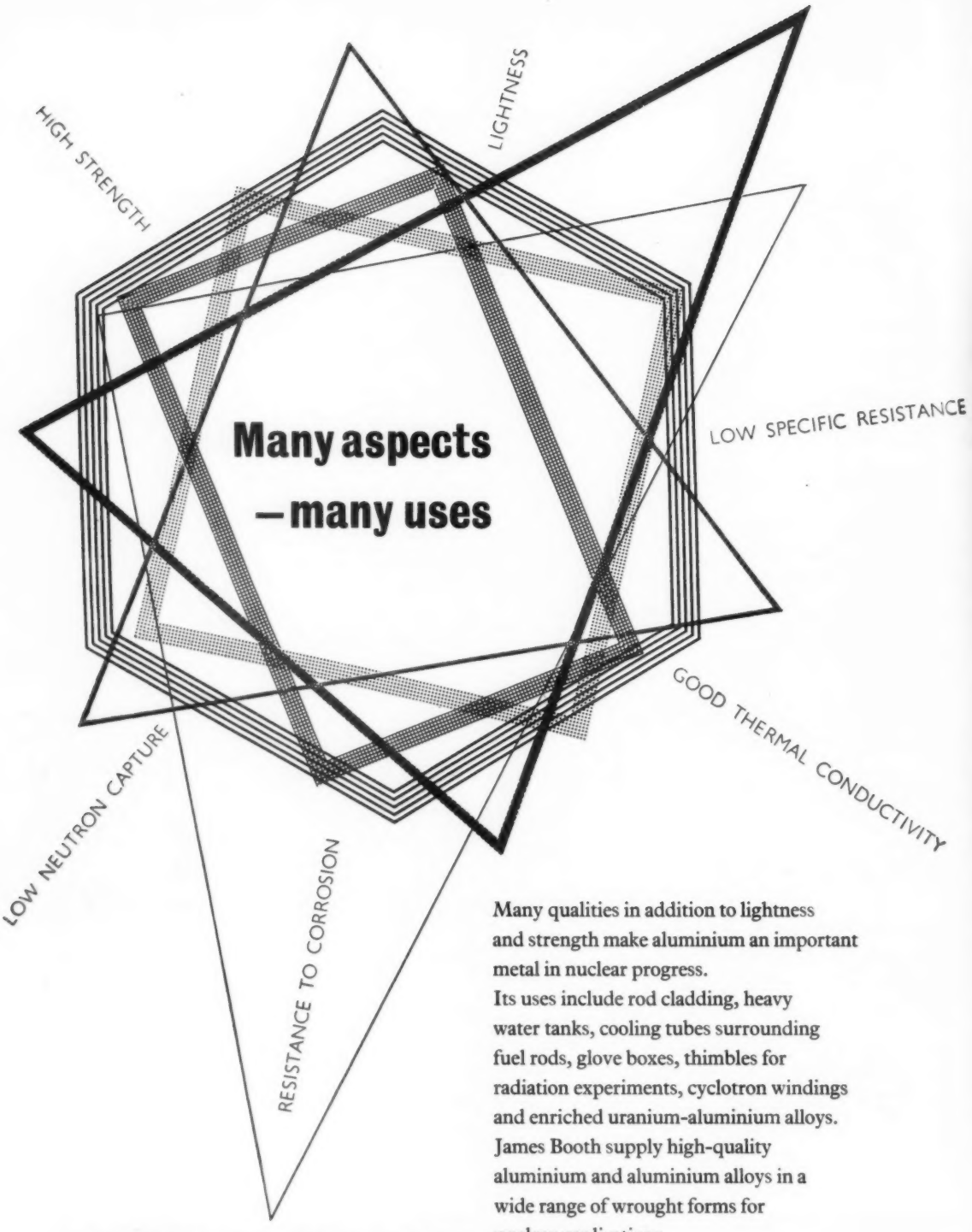

Many qualities in addition to lightness and strength make aluminium an important metal in nuclear progress.
Its uses include rod cladding, heavy water tanks, cooling tubes surrounding fuel rods, glove boxes, thimbles for radiation experiments, cyclotron windings and enriched uranium-aluminium alloys.
James Booth supply high-quality aluminium and aluminium alloys in a wide range of wrought forms for nuclear applications.

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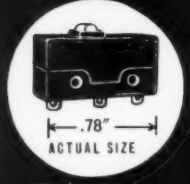
off the cuff . . .



The New BURGESS V-4

* No larger than the average cuff-link
* New mechanism has mechanical life of at least 10 million operations
* Three types of solder terminals available
* Comprehensive range of auxiliary actuators

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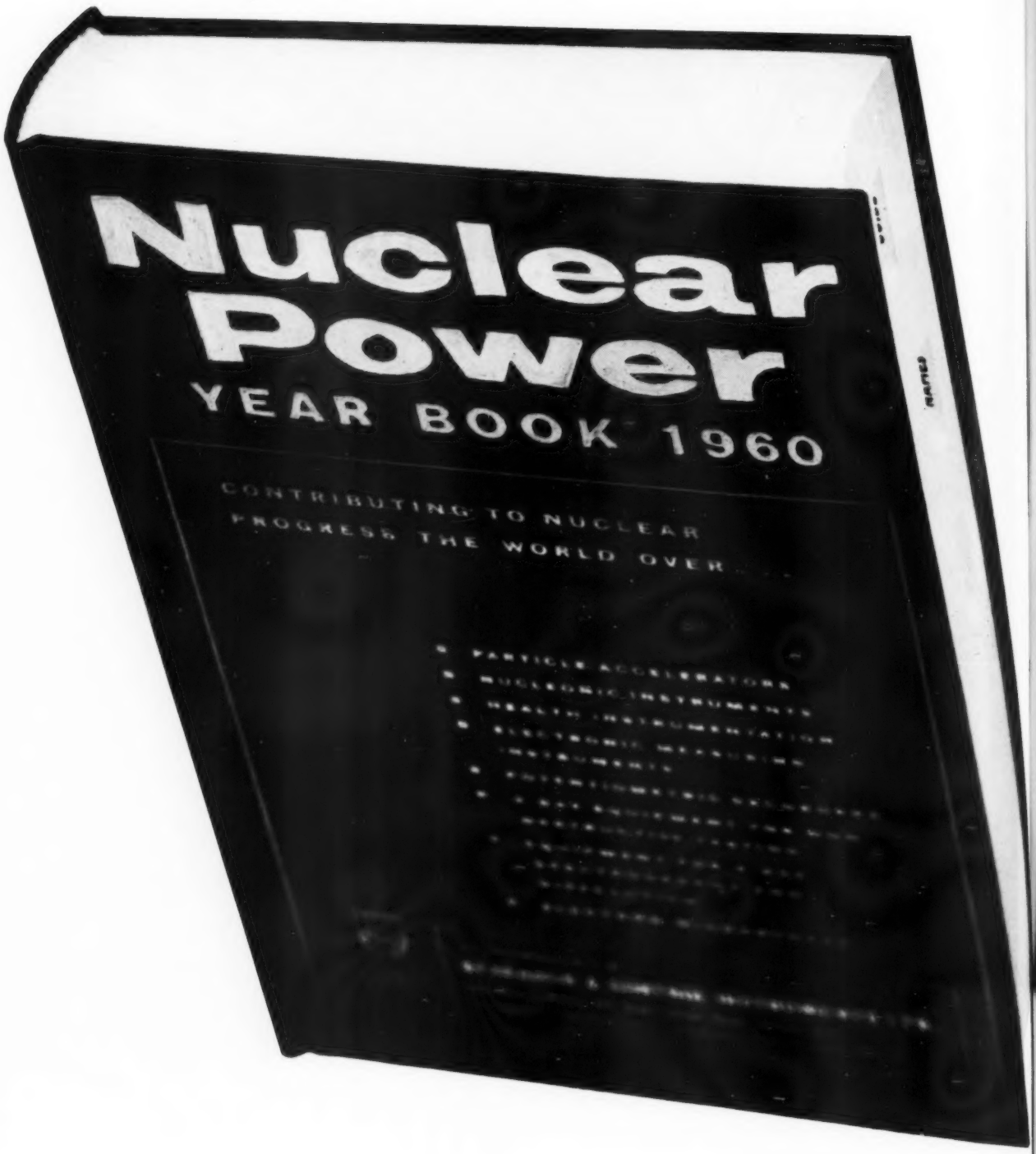
Nuclear
Power
YEAR BOOK 1960
CONTRIBUTING TO NUCLEAR
PROGRESS THE WORLD OVER

THE 1960 NUCLEAR POWER YEAR BOOK & BUYERS' GUIDE

NOW IN ITS 3rd EDITION

the Nuclear Power Year Book and Buyers' Guide is the only comprehensive publication of its kind in the world

CONTENTS

1 1960 Review
An uptodate critical review of the British nuclear power scene, details of the British nuclear contracting groups and the electricity generating authorities, data on British reactors, map of nuclear energy establishments and power stations.

2 World Authorities
The history, organization and plans of all national atomic energy authorities and international bodies. Addresses of establishments and names of leading officials.

3 Technical Data
Articles and tables on reactor physics, instrumentation and special metallurgy.

4 Isotope Section
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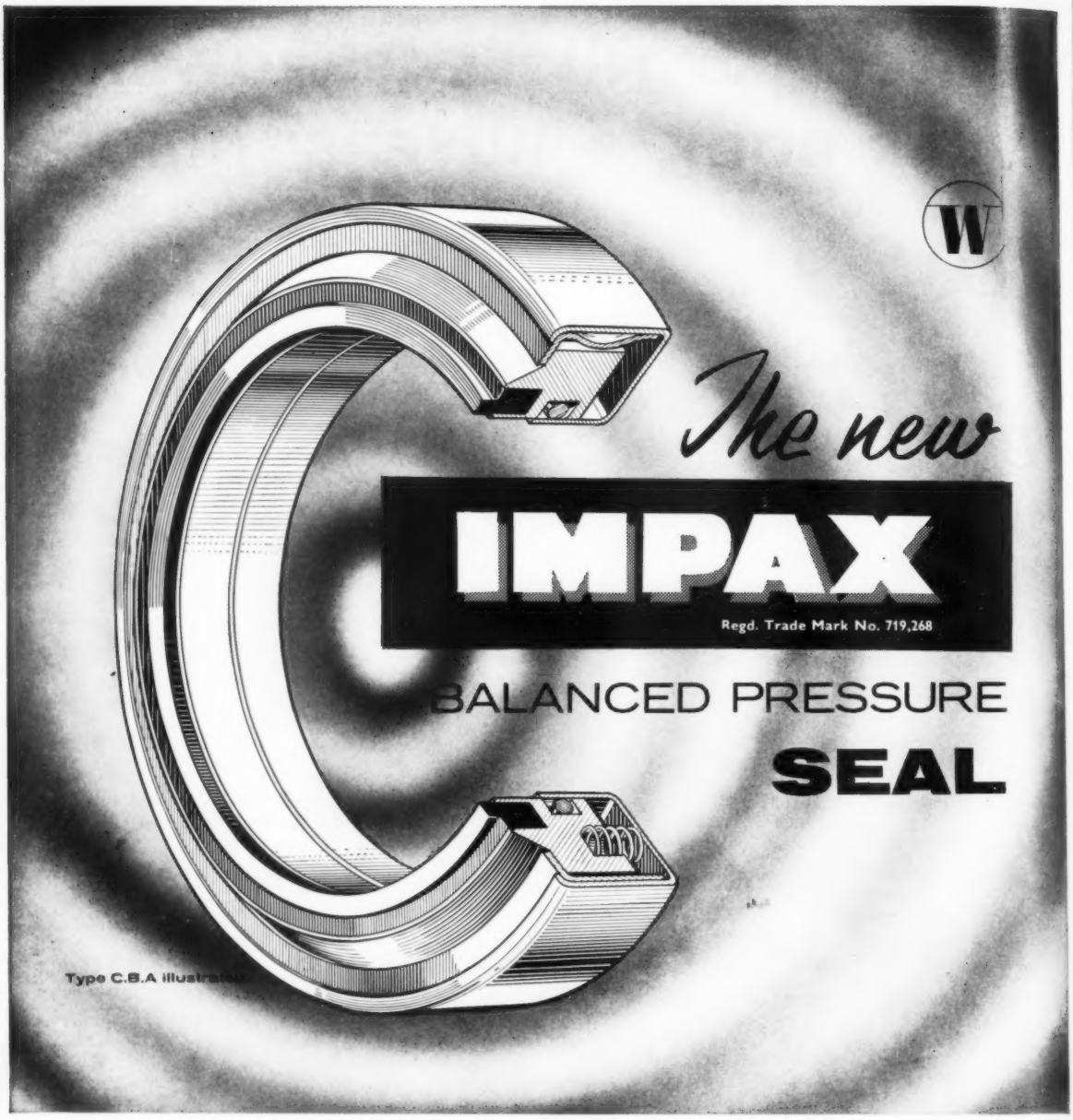

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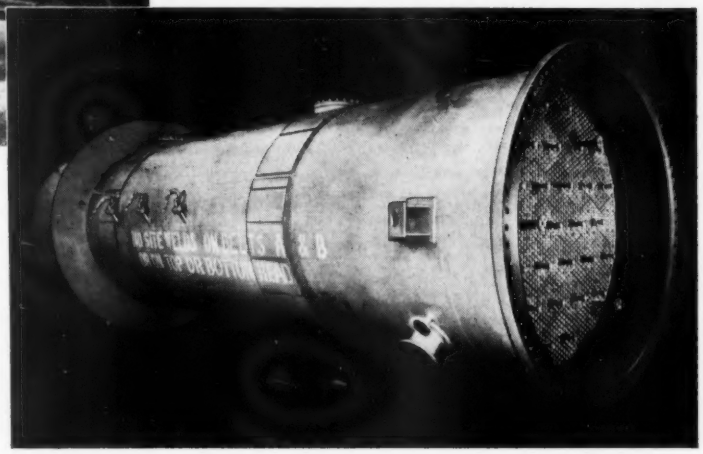
Left: A mild steel jacketed Autoclave to Class 1 construction with electrically driven stirring gear.

Below: This Ethylene Oxide Reactor weighs 135 tons, is 9 ft. 6 ins. in diameter and contains over 15 miles of 1¾ in. dia. catalyst tube.



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The type N.103 is normally supplied for rack mounting but is also available in a metal case.

SPECIFICATION

OUTPUT VOLTAGE: continuously variable between 300 and 3,300 volts positive or negative, with an accuracy of $\pm 1\%$ of dial reading.
OUTPUT CURRENT: at the low-impedance output up to 1mA.
OUTPUT IMPEDANCE: low-impedance output varies with voltage settings but does not exceed 3,000 ohms. High-impedance output: 10 megohms.
STABILITY AND RESETTING ACCURACY: stability for mains variations of $\pm 10\%$ is $\pm 0.05\%$. Drift due to all other causes is within the following limits for the periods stated: 1 hour $\pm 0.05\%$, 100 hours $\pm 0.1\%$, 1,000 hours $\pm 0.2\%$.
A standby switch is provided and when the unit is switched on after a stand-by period any given voltage will be within $\pm$ 0.05% of its previous figure.
RIPPLE AND PULSE CONTENT: ripple, noise and spurious pulses have a maximum level of 500 microvolts at 3,300 volts H.T. at the low-impedance output. At the high-impedance output this is reduced to below 100 micro-volts.

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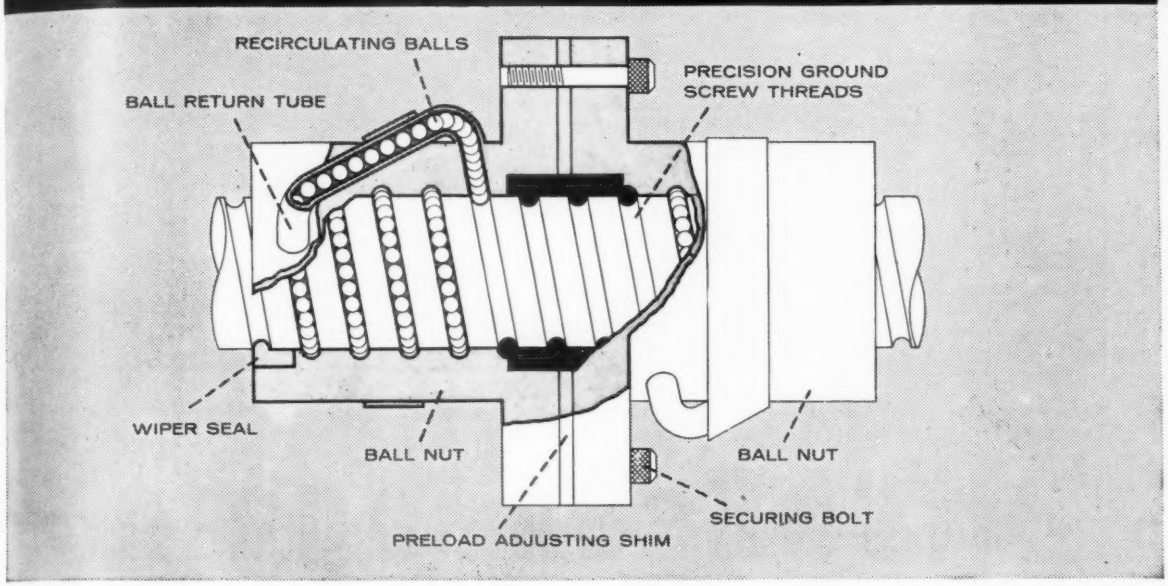
Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



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Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of −52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

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Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

** Complete technical and manufacturing co-operation with Beaver Precision Products Inc., Detroit.*

For further information please write to J. B. Starky, Sales Manager (Beaver Products Division), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

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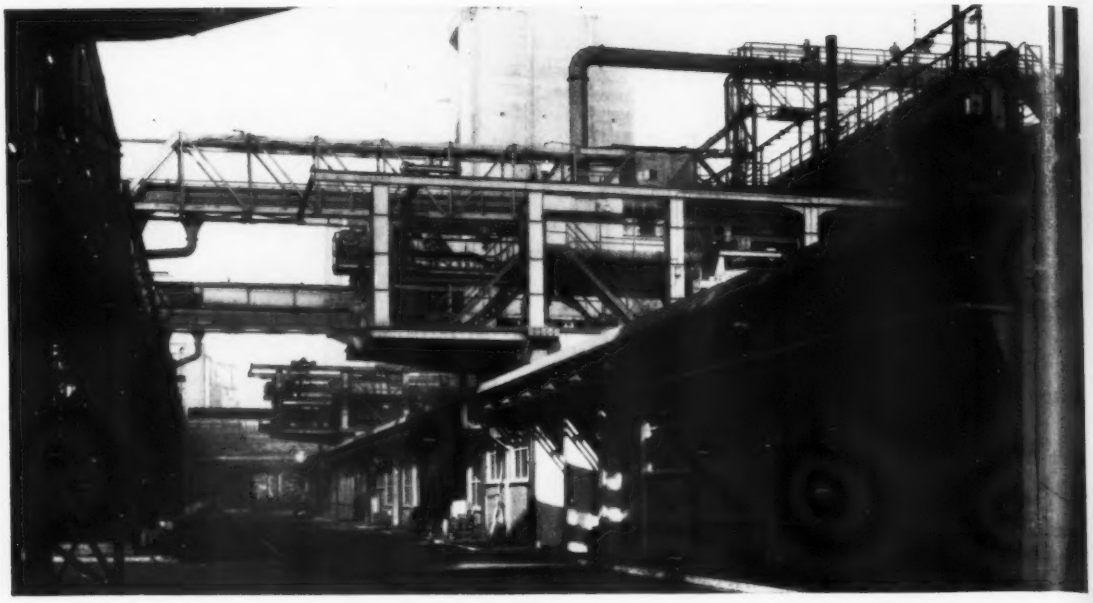

The ram side of the 66 coke oven battery at Manvers Main

Courtesy of National Coal Board & Simon Carves Ltd

MICROsen again —

——— crops up everywhere and not only on cranes and hoists. In this case it is incorporated in E.M.B. Control Gear Equipment for locating the ram beam exactly opposite each oven to eject the red hot charge of coke. The MICROsen, which gives variable speeds ranging from 10% to full synchronous speeds, can be applied to any standard slip ring motor from 2 to 140 H.P.

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Pye at Dounreay

The Pye Instrument Group has supplied all the equipment to the U.K. Atomic Energy Authority for the irradiated fuel element laboratory at Dounreay. In addition to supplying equipment, Pye Ltd. acted as consultants and designers on all matters in that laboratory relating to instrumentation and remote handling. The illustration above shows manipulators working in conjunction with a television camera to handle and measure a sample from the fast reactor.

The Pye Instrument Group consists of: Pye Atomics Division; Pye Industrial Television Division; Faraday Electronic Instruments Ltd.; Labgear Ltd.; W. G. Pye & Co. Ltd.; Pye Telecommunications Ltd.; Unicam Instruments Ltd.; W. Bryan Savage Ltd.; W. Watson & Sons Ltd.

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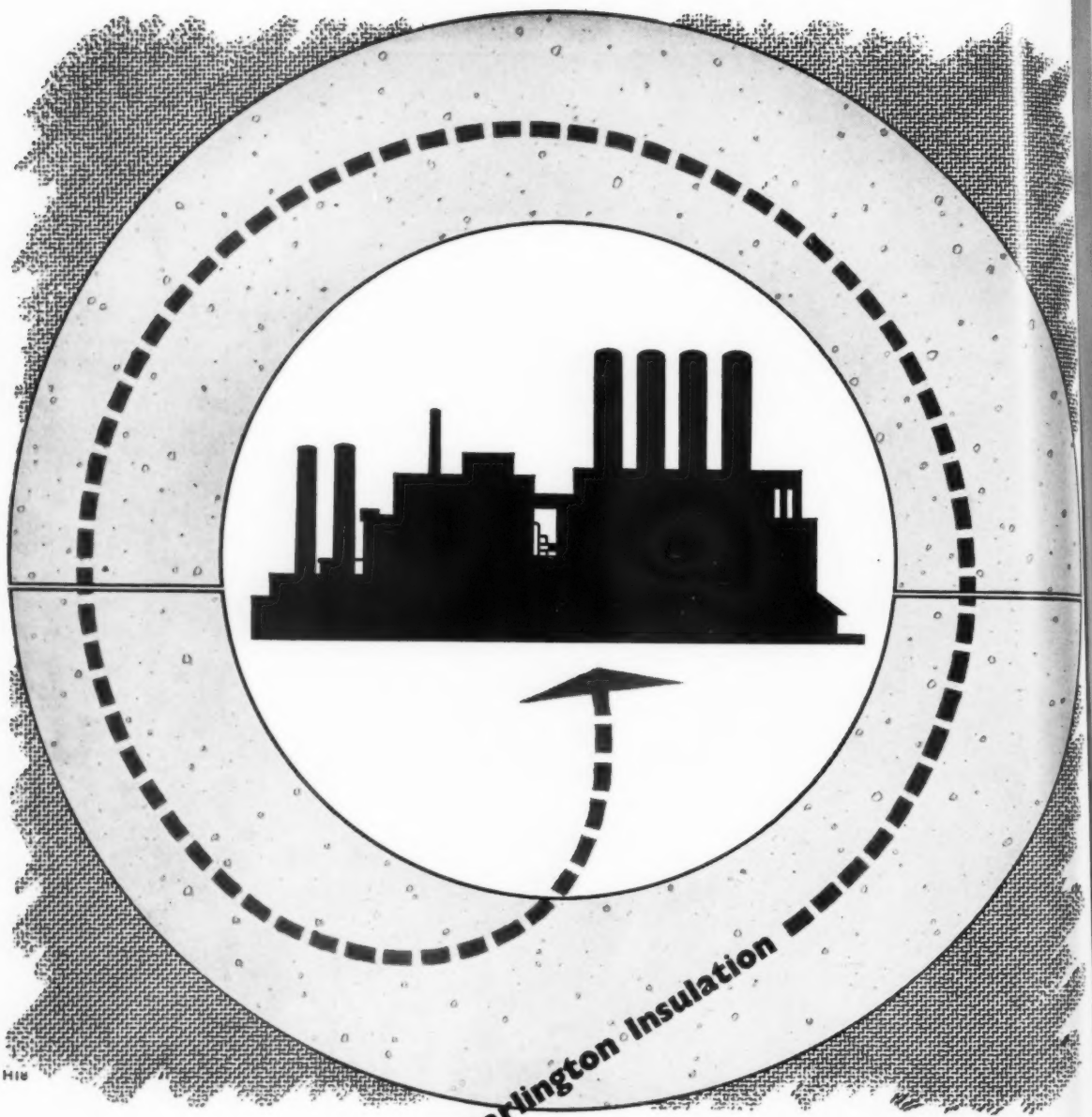

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Year after year the Central Electricity Generating Board's list of power stations with the highest operating efficiencies includes a majority of stations where the efficiency is guarded by Darlington Insulation. In the 1957 list, for example, the top four stations are Darlington insulated.
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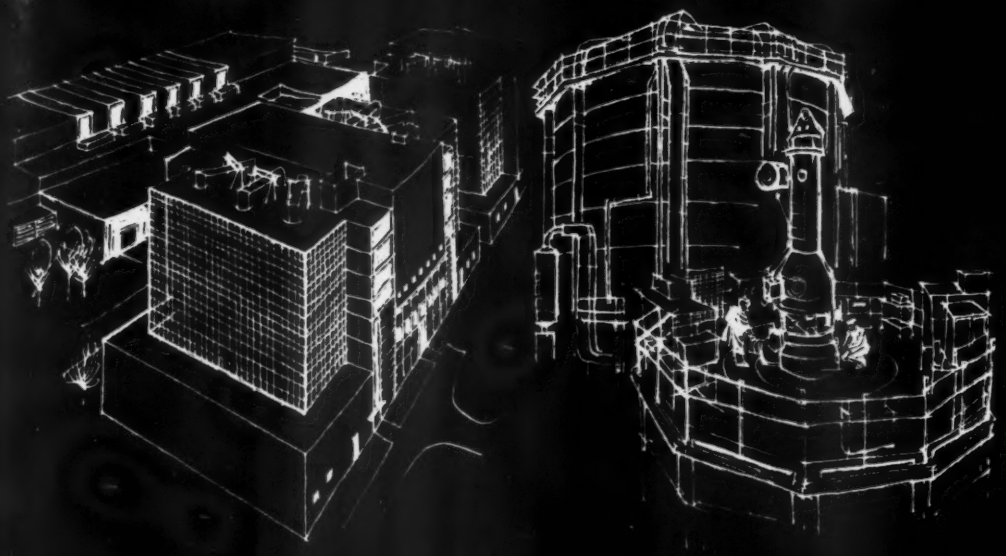

in the research and power fields

Head Wrightson hold a commanding position in world Nuclear Engineering, having supplied Research Reactors and Specialised Nuclear Equipment to Harwell - Aldermaston - Dounreay - Sydney, Australia - Risø, Denmark - and Julich, Germany.

As a member of The Nuclear Power Group, **HEAD WRIGHTSON** are co-operating in the provision of Nuclear Power Stations at Bradwell, Berkeley, and Latina - Italy.

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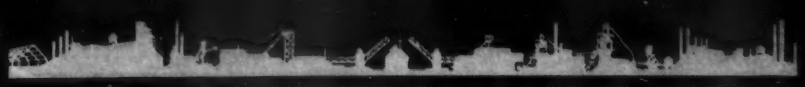

P4554

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Interesting, of course, Smithers . . . .

but scarcely fundamental

Take heart, Mr. Smithers. Your learned friend may be rising seventy by the time another fundamental discovery really stirs his blood.

As a technologist, Mr. Smithers, you rightly direct most of *your* reading time to the study of as many applications as possible of principles that already exist.

That, Mr. Smithers, is the simple reason why *Nuclear Power* confines itself to *applied* science. There are so many new applications yet to come (some may even be *called* discoveries); so many existing that could be extended; so many exciting instruments and systems to make the most of —so much to *do*!

One last word, if we may, Mr. Smithers. Your subscription to *Nuclear Power* runs out in June. We know from statistics that *Nuclear Power* is the journal you make the most use of. (Is it not the heart and soul of your private indexed reference file?) So, Mr. Smithers, if you have not already renewed, could we direct your attention to the pre-paid postcard you will find facing page 82.

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The standard of reliability of STC components is set by the vital roles of the navigation and communications equipments in which many of them are used. The consequent employment of top grade materials and high degrees of skill and care in manufacture ensures that all users of STC components may have the fullest confidence in them.

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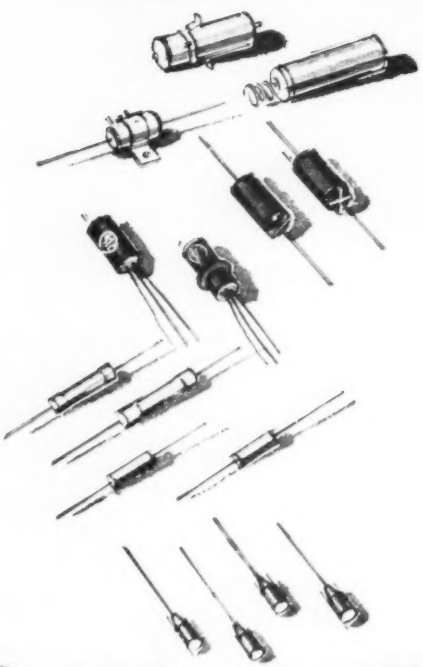
Special Valves · Selenium Rectifiers
Silicon Rectifiers · Silistors
Suppressors · Transistors · Thermistors
Transformers · Zener Diodes

Get to know about STC Components—write for booklet M/103 which lists all components and their relevant technical literature.



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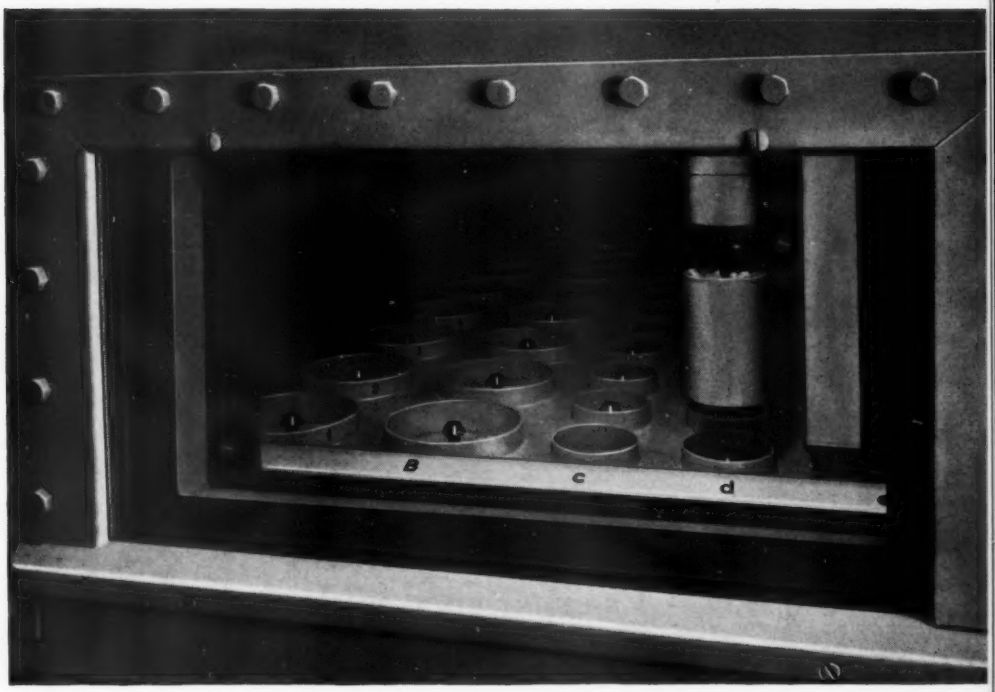

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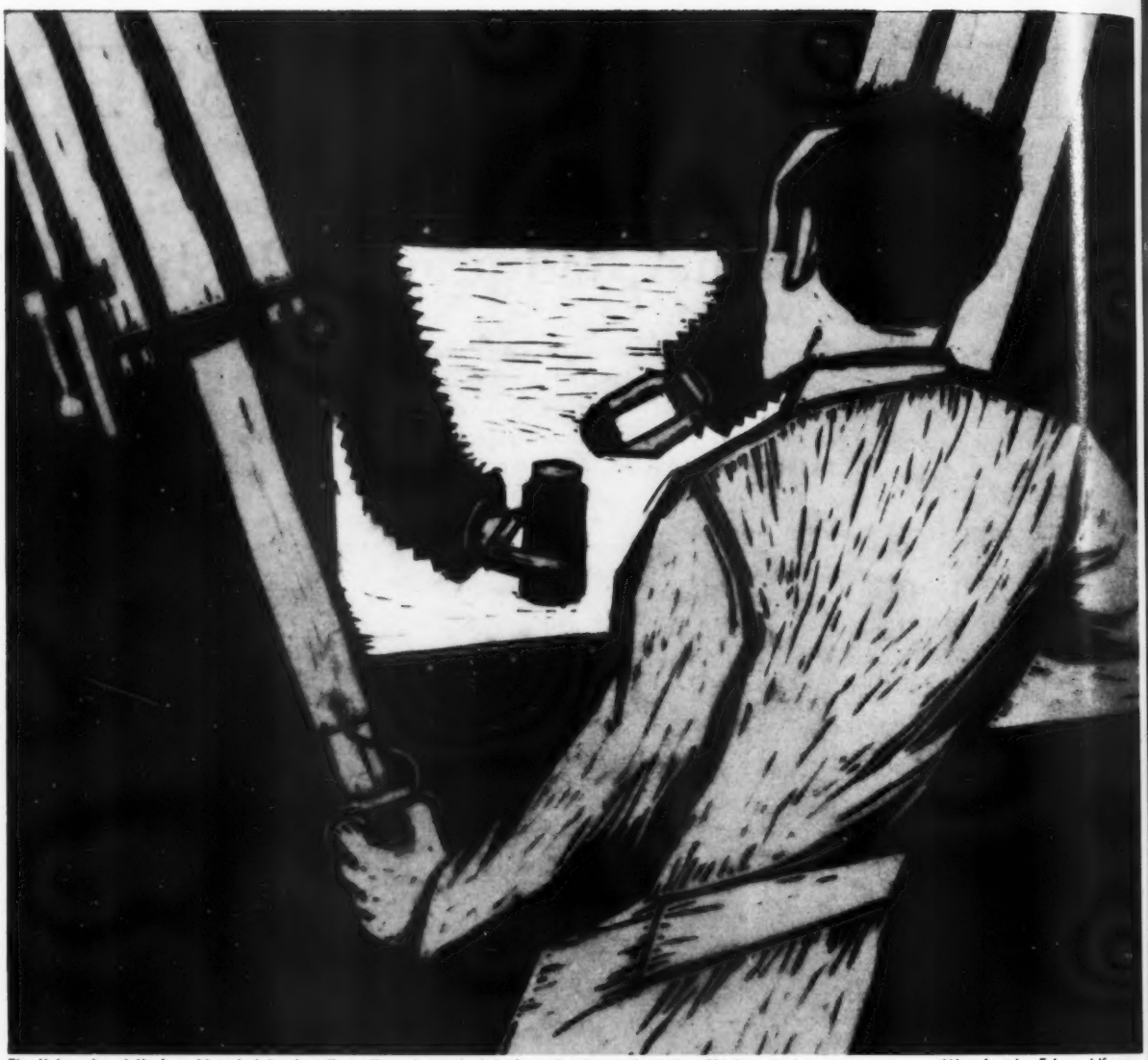

The "slave-hands" of an AI technician handle radioactive materials through a hot cell window 3½ feet thick. *Woodcut by Edward Kysar.*

Let A.I.'s experience guide your Nuclear Power Program

The largest privately-owned facility in the world for remote handling of radioactive materials is located at Atomics International's 290-acre field laboratory near Los Angeles. Here the men who pioneered the creative peacetime uses of atomic energy are applying their 14 years of experience to developing advanced nuclear reactors and associated equipment.

Much of AI's work has been on projects for the U.S. Atomic Energy Commission. This includes the Organic Moderated Reactor Experiment at the National Reactor Testing Station in Idaho and the Sodium Reactor Experiment in California. AI has also built and is operating SNAP II, a 100-kilogram prototype reactor designed to produce 3 KW of electricity for space vehicles.

With some of the most sophisticated facilities in the world at their disposal, the men at AI are now conducting studies for large power station reactors in the United States and Euorpe. Two reactors are now actually under construction under AEC programs—an Organic Moderated Reactor in Piqua, Ohio, and a Sodium Graphite Reactor in Hallam, Nebraska. Smaller research reactors have been built by Atomics International for Denmark, Germany, Italy, Japan, Puerto Rico and several sites in the USA.

For details contact: ATOMICS INTERNATIONAL, Canoga Park, California, USA. Cable address: ATOMICS.

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EVERSHED

VISIT STAND K 458 AT THE I.E.A. EXHIBITION

RECORDER CONTROLLER

A servo operated recorder to provide a permanent record of the measured value, has been added to the already comprehensive specification of the Evershed Mark 4 Controller which has found wide application throughout the world in all types of industries. Ingenious design allows a full 4" chart display without increase of the panel cut-out which remains at the international standard of 144 × 144 mm.

The new controller, in two units, is completely self-contained, and embodies many proven features, *e.g.*, exchangeable printed circuit boards, built-in test and calibration facilities, bumpless transfer, etc.

EVERSHED SUPERVISORY CONTROL

'Transmission of 40 measurements over one pair of transmission lines, with simultaneous control signals (and positive confirmation) in the reverse direction over the same pair of lines'—this is the significant feature of this continuously cycling system. Added to this are: automatic monitoring of the system's correct operation, and automatic visual and audible alarms for dangerous conditions, etc.

Alternative facilities (for which the scanning cycle is rendered inoperative) are: 1. Selection "on-demand" of any of the measuring control points, or 2. Automatic initiation of the scanning cycle through changed conditions at a control point.

ANALOGUE TO DIGITAL CONVERTER

This new converter enables analogue measurement signals of Evershed Process Control Equipment to be presented in digital form! The instrument is designed to work under industrial conditions and is fast enough to meet all industrial measurement requirements. The output circuit can operate series or parallel displays, and/or print outs etc. It is essentially a simple device which keeps routine maintenance and service requirements at a minimum.

SOLIDS LEVEL TRANSMITTER

Evershed's comprehensive range of measurement transducers is further enlarged by this instrument which is designed to sense the level of granular solids in storage. Its output signal is suitable for application to a Process Controller, or for remote indication and/or recording.

A special feature prevents submergence of the sensing device by hopper discharged materials.

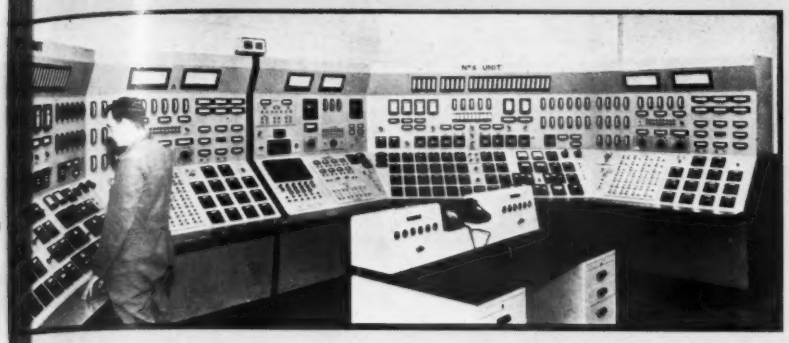
TEMPERATURE MEASUREMENT

This transmitting resistance thermometer is a fully transistorised, highly accurate instrument generating an output signal suitable for operation with Evershed Process Control equipment. It requires a minimum of attention over extended periods, permits easy matching to existing transmission lines, embodies built in test facilities, and calibration check facilities which do not need skilled personnel.

ALL-ELECTRIC VALVE POSITIONER

An all-electric Positioner, which operates in conjunction with a specially designed transistorised control/feedback amplifier, is now added to the range of Evershed Electro-pneumatic and Electro-hydraulic Positioners. The all-electric Positioner provides a 500 lb. thrust with an adjustable stroke of up to 2", and is capable of a response time of 6 seconds per inch.

Exceptionally modest power consumption and practically no routine maintenance requirements (lubrication four times per year is adequate) combine to make this advanced Positioner particularly attractive. Even under most severe operating conditions it will maintain a sensitivity of 1%.

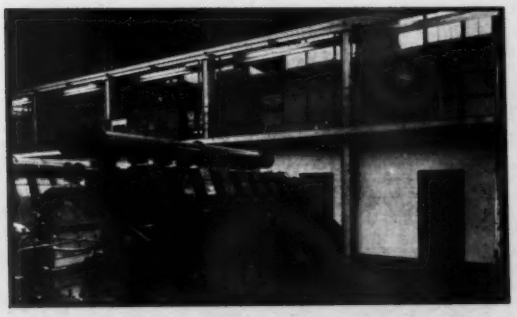


Boiler control panel at Little Barford Power Station—the first in Great Britain to be electronically controlled.

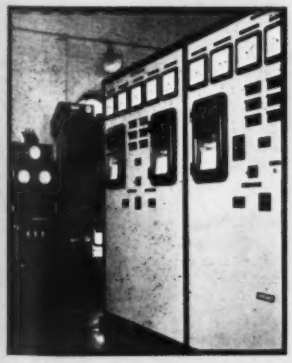
Part of Wissington sugar refinery control panel showing Evershed miniature recorders and process controllers.

Movement and levels of crude oil are controlled from this panel in a Kuwait Oil Company tank farm.

The supervisory panel at the Jersey Sewerage Board's installation at Bellozane. Measurements from six out-stations are sequentially sampled and continuously displayed. Remote control is also provided.



Colchester Water Works uses Evershed multipoint telemetering equipment for control, indication and recording at this main station and two remote stations.



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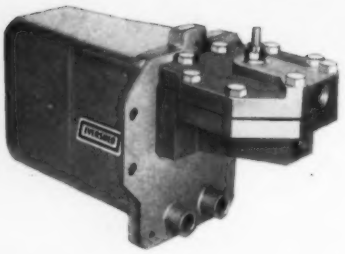


FLOW OR DIFFERENTIAL PRESSURE TRANSMITTER — TYPE ER 125

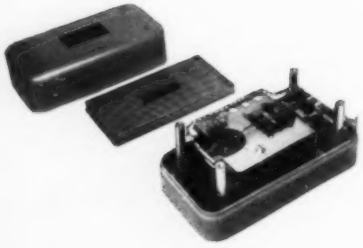
Designed for the control and remote indication of differential pressures up to 200 in. W.G. and at static pressures up to 1,000 p.s.i. Suitable for application to processes involving oil, viscous or corrosive fluids as well as water, steam or gases.

For further information ask for leaflet S.S.1.

GAS PRESSURE OR DIFFERENTIAL PRESSURE TRANSMITTER — TYPE ER 83

This transmitter embodies a limp diaphragm, and is capable of accurately measuring extremely low gas pressures. To provide local indications, a milliameter is included in the transmitter housing.

For further information ask for leaflet S.S.3.



SIMPLE COMPUTER — TYPE ER 92

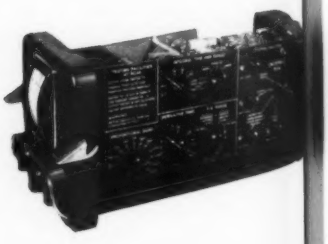
This instrument is used to evaluate continuously the variables and constants of a controlled process. The operations performed are: Addition; subtraction; multiplication of two variables or of a variable by a constant; division of two variables, or of a variable by a constant and *vice-versa*; squaring; square root extraction.

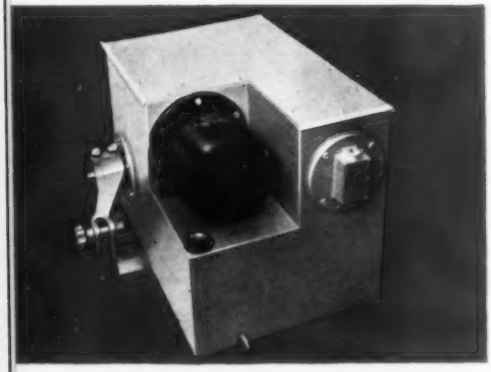
For further information ask for leaflet S.S.10.

ELECTRONIC PROCESS CONTROLLER MARK IV

The Evershed 3-term Process Controller operates in conjunction with Evershed Electronic Repeater Transmitters which provide the measured value signal, and when compared with a manually adjustable 'desired value' current, develops a controller output signal which contains 3-term circuitry (*i.e.*, proportional, integral and derivative) components.

The output signal may be used to operate Evershed electro-pneumatic, electro-hydraulic or electro-mechanical positioners, valves, dampers, etc., in order to maintain the process under control in the desired manner. For further information ask for leaflet S.S.12.





STANDARD ELECTRO-HYDRAULIC VALVE POSITIONER

Of robust construction, this equipment which incorporates the hydraulic jet pipe relay principle, can be used to operate the heaviest dampers or valves. It is completely self-contained with its own motor driven pump, and accurately positions the damper or valve according to the value of the signal received from the control system, irrespective of the magnitude of forces to be overcome.

For further information ask for Publication No. 520.

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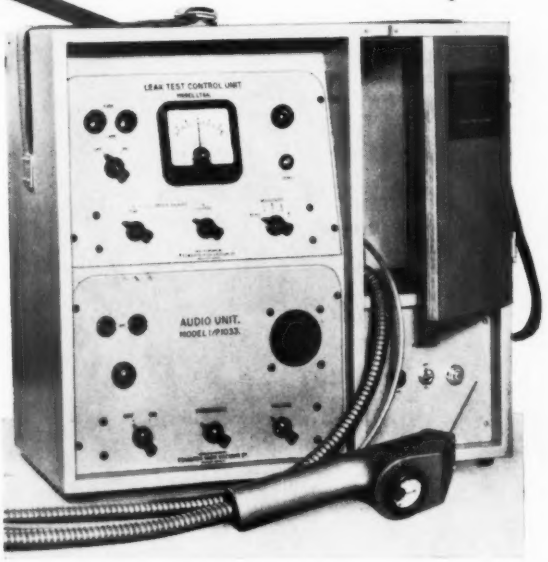

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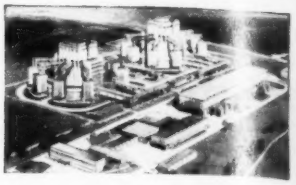

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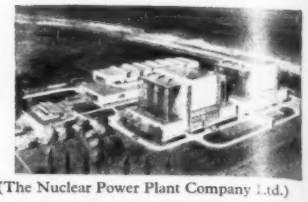

BRADWELL (The Nuclear Power Plant Company Ltd.)

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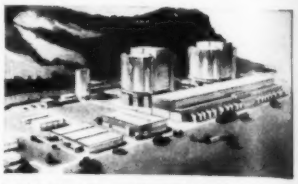

HUNTERSTON (G.E.C.—Simon Carves Group)

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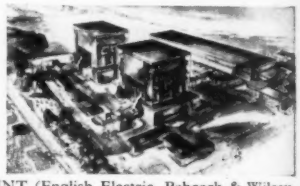

HINKLEY POINT (English Electric, Babcock & Wilcox, Taylor Woodrow Atomic Power Group)

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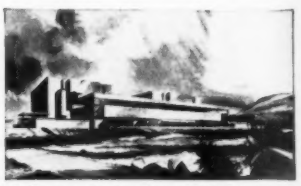

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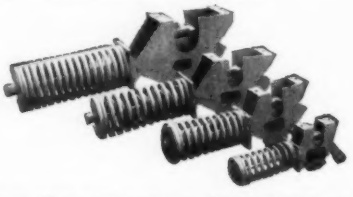

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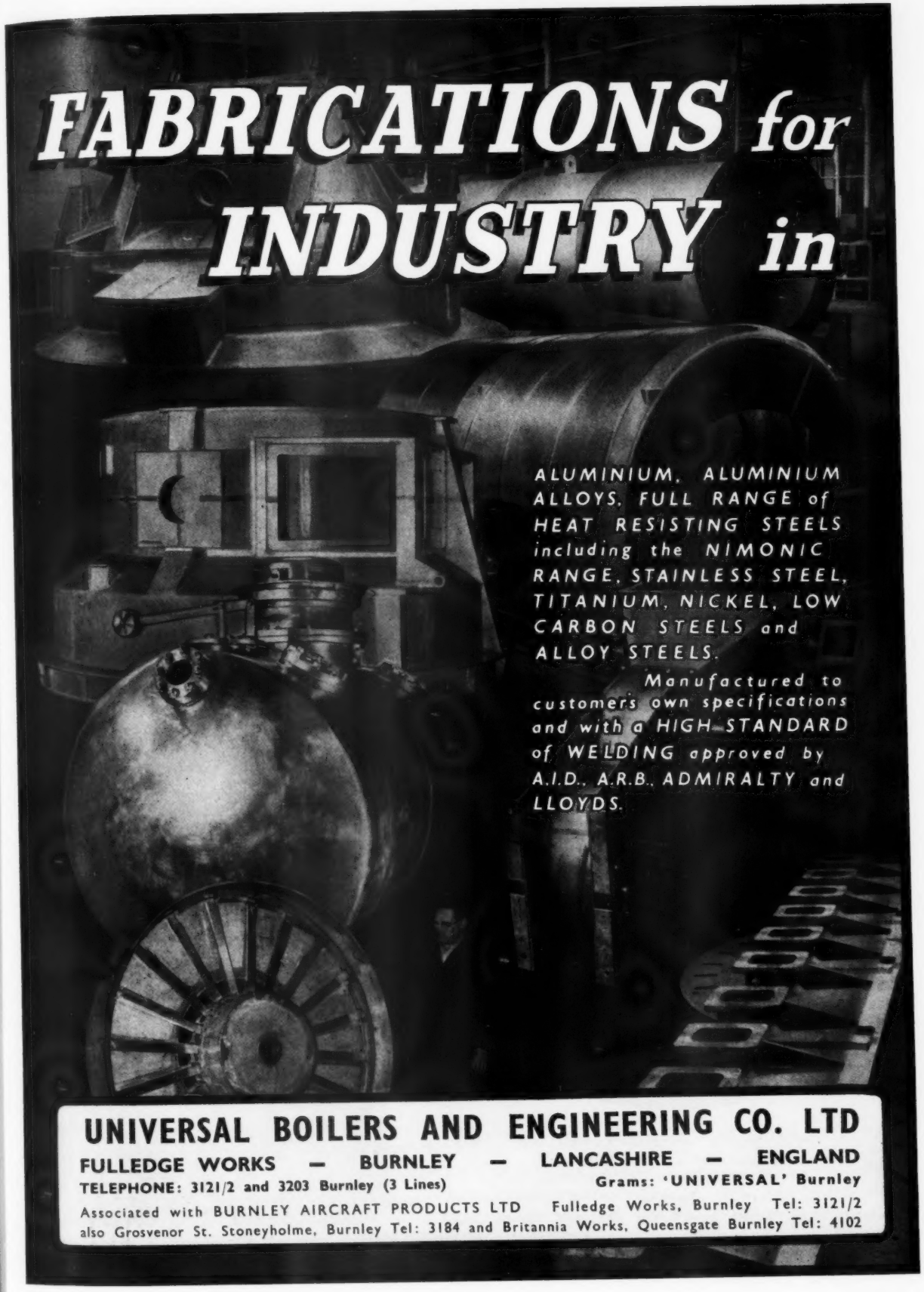
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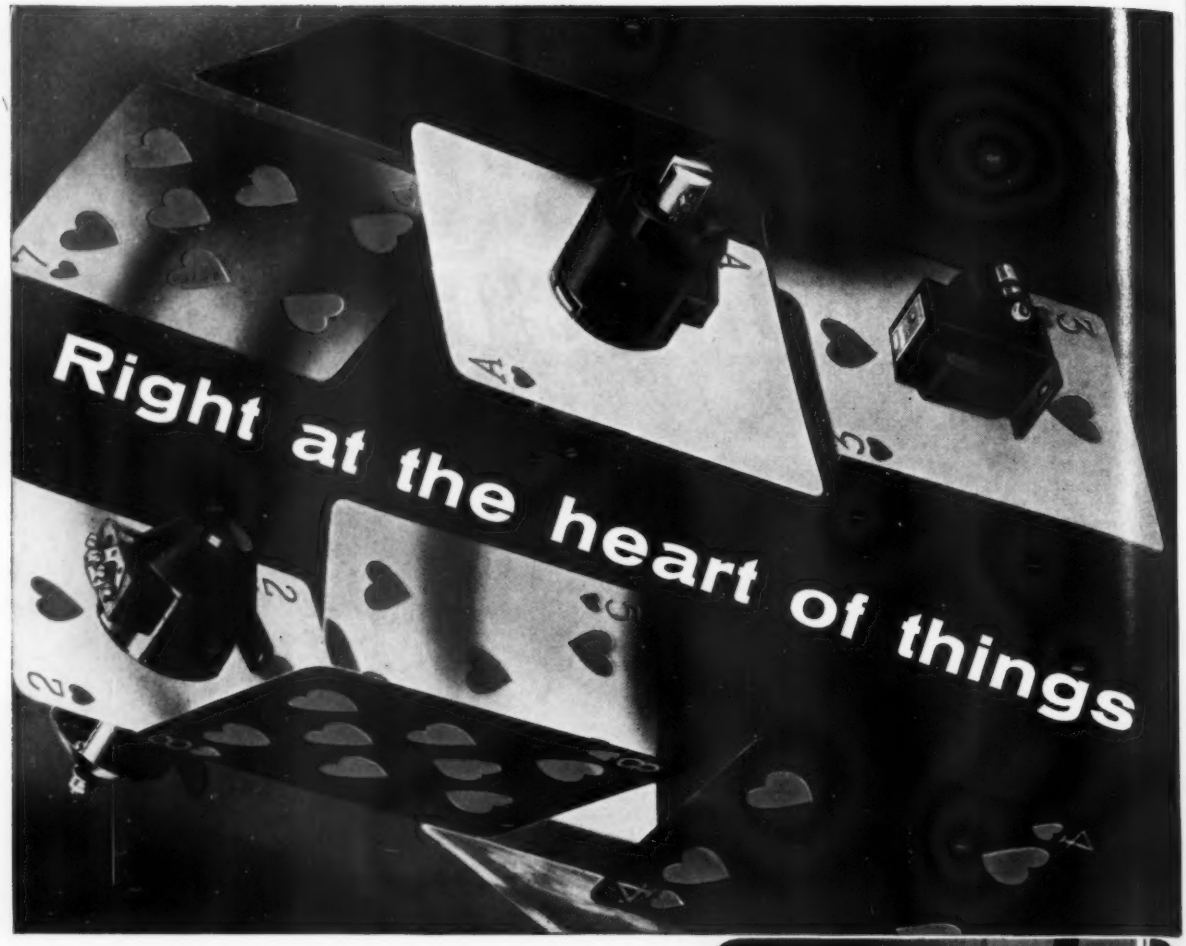

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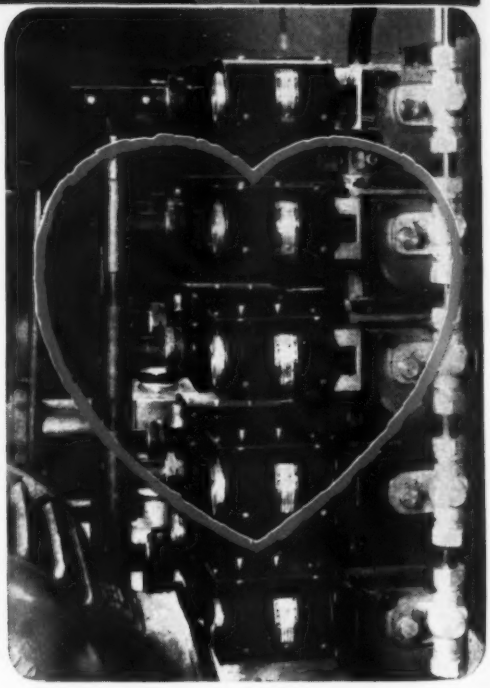
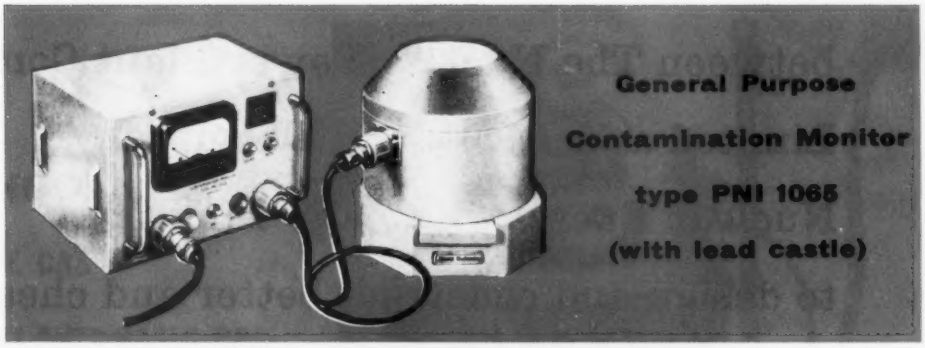


Bank of Westool Solenoids operating hydraulic valves. Photograph by courtesy of Towler Brothers Ltd, Leeds.

TIB. 131

Radiation Monitoring



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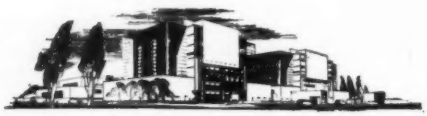
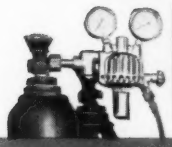


TGA NP 15 B



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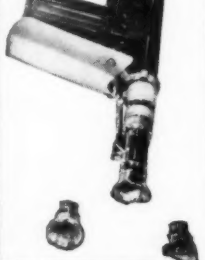

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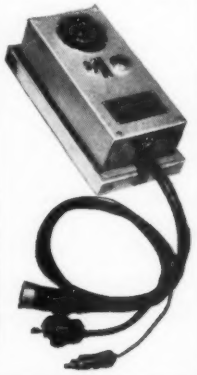

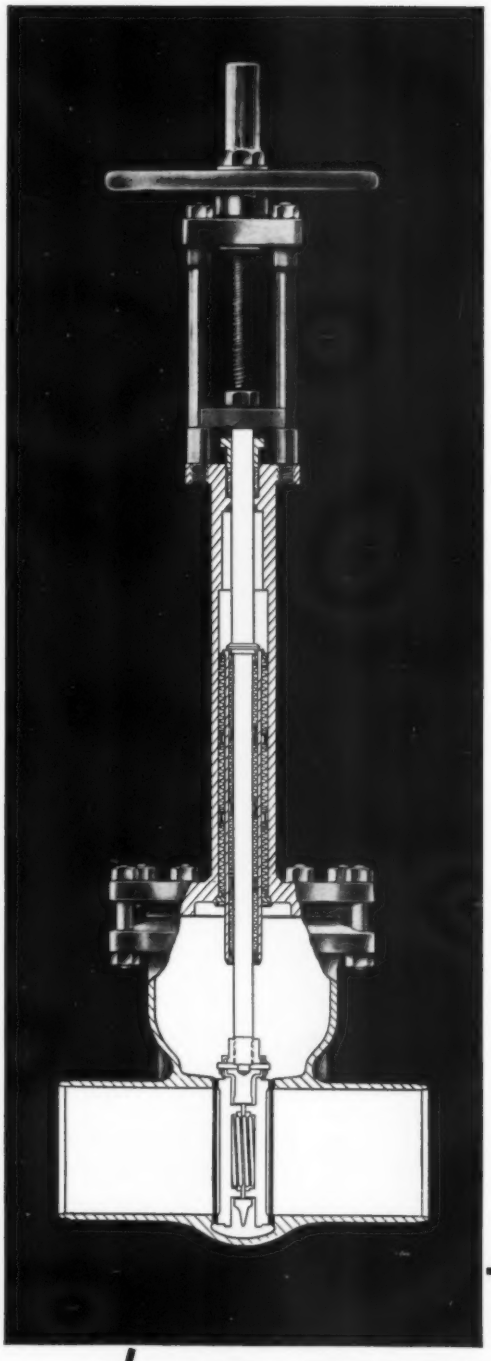

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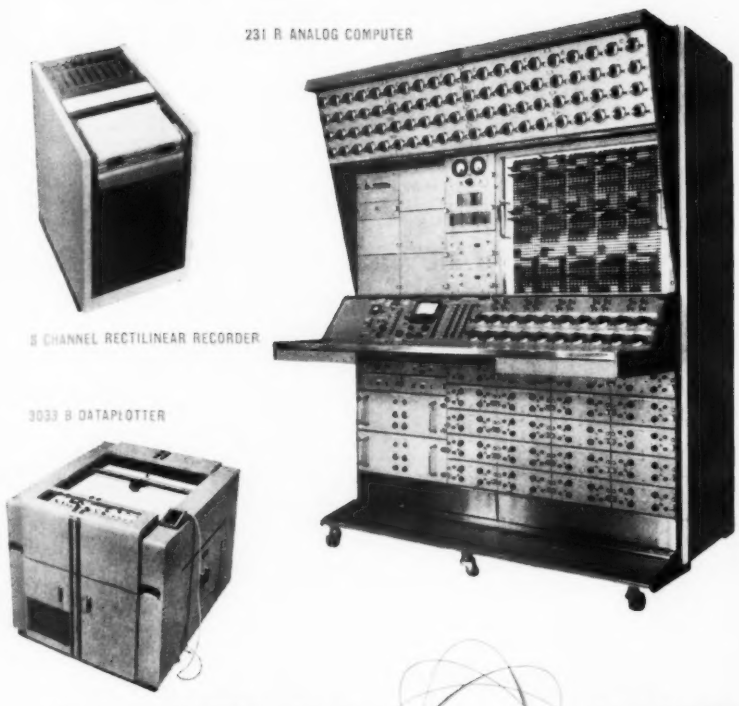

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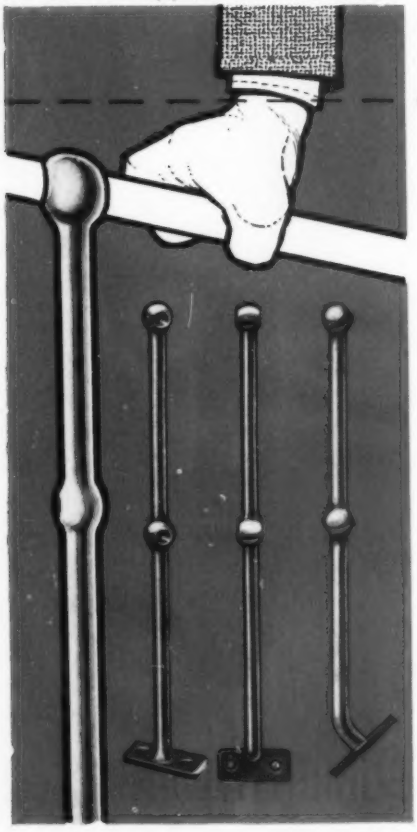

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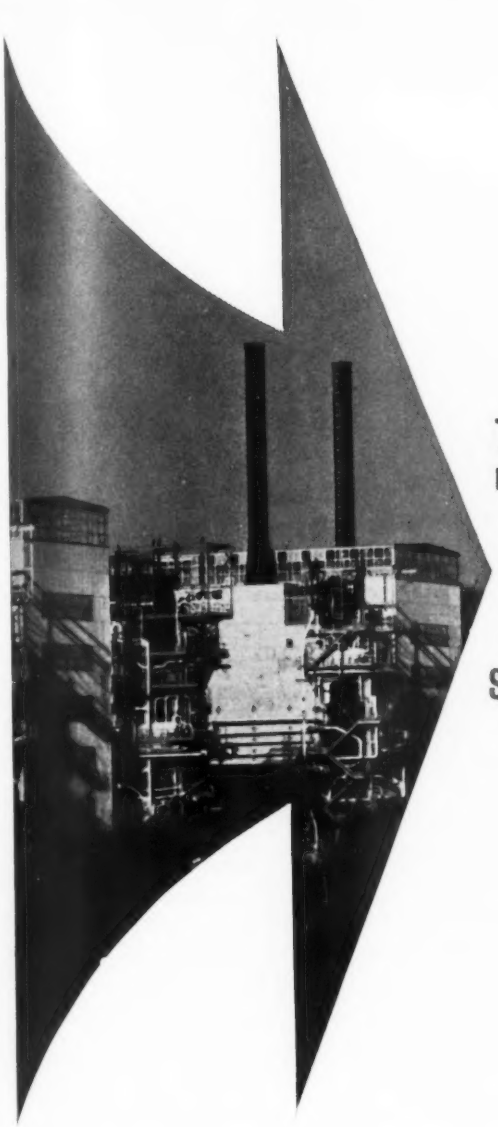

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JUNE 1960 VOLUME 5 NUMBER 50

VIEWPOINTS *letters to the Editor*

Reactors for teaching

SIR: It is noteworthy that there is a flood of small nuclear reactors (up to 100 kW) now being made available on the commercial market. It is claimed that these reactors provide adequate teaching facilities for universities and private laboratories, but I feel such a claim can hardly be justified.

The use of a small reactor for teaching is limited by the inflexible design of such a reactor and the restrictions imposed as a result of the safety precautions. For example, only the control and approach to criticality can be demonstrated. Different control rod positions can be used, but neither the moderator nor the cooling system can be changed in any way. It is unlikely that a sufficient surplus of fuel elements would be made available to illustrate the behaviour of core geometries differing even slightly from the most efficient one.

A carefully designed Reactor Simulator capable of demonstrating a wider range of degrees of freedom would be of much greater value in teaching reactor physics and reactor engineering.

The potential value of a 100 kW reactor for original research up to or beyond D.Phil. standard is questionable. The majority of fundamental research work in physics and nuclear engineering using a reactor as a neutron source (e.g. for neutron diffraction, irradiation damage and shielding experiments) requires intense neutron beams and hence the large reactors at atomic energy establishments. The present trend is towards the use of even more intense beams, so that to contemplate the use of weak thermal neutron fluxes from small 100 kW reactors is rather out of date.

A small reactor is, of course, likely to be useful in radiation chemistry and for the production of isotopes. However, in the fields of radiation medicine and biology, where careful control of experimental conditions is required for any quantitative studies, a small reactor would hardly be suitable since it is a 'dirty' source of radiations.

The installation of these reactors in urban areas does little to increase their potential usefulness. Their siting on university or industrial premises necessitates stringent safety regulations because of the biological hazards involved. These regulations, in turn, are extremely likely to restrict the scope of any research.

It is obvious that if these reactors were of fundamental value in teaching or research. their merits might outweigh their disadvantages. However they appear to have comparatively little scientific value and so it is most disturbing to note the efforts being made to create a market for these reactors in universities and private laboratories.

Southampton R. G. SCURLOCK

Lack of export sales

SIR: Your May editorial makes the telling point that uncompetitive credit terms have hampered export sales of British nuclear power stations. Is it not also possible that the consortia have failed to fully appreciate that most technically advanced countries will eventually develop and construct their own nuclear power systems? I ask this because fairly frequently one hears of American firms forming subsidiaries in countries such as France and Germany but rarely of British firms doing the same.

Another point that does puzzle me is that one hears of 'turn key' contracts being submitted by British firms. Surely this method is a bit antiquated or do the export sales prove otherwise?

Edgbaston, Birmingham. LEWIS WYNSEL

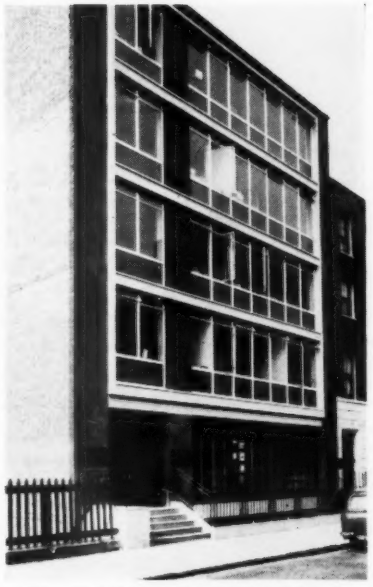
Small power reactors

SIR: The small space allocated to British activities in your excellent survey of small power reactors (May issue) brought home a truth that we are learning to live with, i.e. that this country is a long way behind America in this field and that the gap is increasing. Furthermore, of the few British companies willing to build small reactors, nearly all have arrangements with American companies and are presumably relying heavily on them for basic data. That British industry itself cannot be blamed for this is reflected in the startling fact that while the first of many contracts for the design of a small reactor was awarded to an American company in December 1954, the number of contracts to British companies for a complete small power reactor is zero—*over five years later.* If the UK government has any intention at all of helping British industry in this matter it must obviously do something very soon.

Your survey was devoted to pressurized water, boiling water, and organic moderated reactors and thus did not mention gas cooled and heavy water moderated steam cooled reactors which are being worked on by British companies. If these are not possibilities for immediate construction, this is surely all the more reason for an increased effort by Britain.

Harrow, Middlesex. EDGAR SEELEY

The Editor welcomes correspondence for publication.



Rowse Muir Building Completed

Featured above is the new Rowse Muir building in Charlotte Street, London, W.1, which has now been completed. The actual move from the former premises in nearby Percy Street took place some time ago but only recently have the builders departed after putting in the final touches. The new building is the headquarters of all three of the Rowse Muir technical journals, Nuclear Power, Control, and Machine Age.

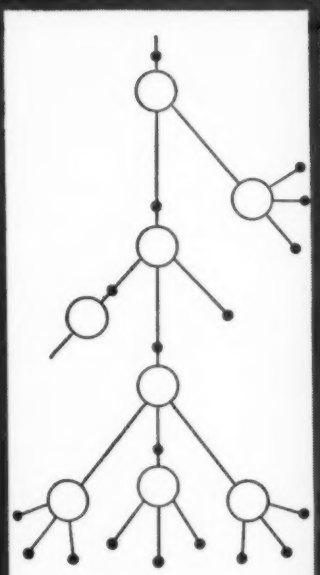
ZIRCONIUM 10
COMMERCIALLY PURE
Reactor Grade

ZIRCONIUM 15
COMMERCIALLY PURE
Hafnium Bearing

ZIRCONIUM 20
CONTAINING TIN, IRON, CHROMIUM, NICKEL
Reactor Grade

ICI

ZIRCONIUM



ZIRCONIUM 25
CONTAINING TIN, IRON, CHROMIUM, NICKEL
Hafnium Bearing

ZIRCONIUM 30
CONTAINING COPPER, MOLYBDENUM
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OPINION

No Insurance

The news that the power station at Oldbury is to employ Magnox canning will disappoint many who had hoped for an early change to the advanced gas-cooled reactor. However, as this journal stressed in 'Opinion', March, the technical problems associated with this type have by no means been settled and the Oldbury decision will allow more time for them to be overcome. The Atomic Energy Authority has not only to satisfy itself that the reactor is technically feasible, but the Central Electricity Generating Board as well, who after all is the customer. One fact, however, is becoming increasingly clear and that is that the reactor, as a type, is proving more intractable than was expected two years ago, and the possibility of its unsuitability as a basis for a programme of commercial power stations must be faced.

What other possibilities are there? As a result of the early decision to concentrate almost entirely on one system, the different states of development of the atomic energy industries in this country and America is now quite startling. The Americans have large-scale experiments and even commercial power stations scheduled or already under construction for a variety of reactors. The UK has developed only two types, the gas-cooled graphite moderated reactor and the fast-breeder, and the entire programme of commercial stations for the next ten years is based on the former. It now seems possible that this base is too narrow. Furthermore it may soon be too late to rectify this. The Atomic Energy Authority and the CEGB could, of course, delay building any other type of nuclear power station indefinitely, but if other systems than the gas-cooled graphite moderated reactor prove in the end to be most useful for world-wide power generation, the chances of British industry gaining a share of the export market for complete reactors or components will be very small.

Some time ago, the Atomic Energy Authority came to the conclusion that perhaps another type should be developed as an insurance against the possible failure of the AGR. It announced that work had been started on the heavy water moderated steam cooled system. Investigations seemed to show that this type offered no economic advantage and little more has been heard of it except that work on other types using heavy water as a moderator is in progress.

It is time to end this over-cautious policy. Research—mostly outside the UK—has shown that it would be technically worthwhile to construct large-scale experiments here for an organic moderated reactor and at least one type of water reactor. Admittedly they have not all been shown to be economically competitive, but the difficulties experienced with the AGR—an attractive proposition economically—only emphasize that engineering feasibility should be the only grounds for choice in the present stage of development of atomic energy. To tie a whole programme to one type before it has been proved, while rejecting proven types as uneconomic, is unwise. No doubt the AGR problems will be solved, but they will have served a useful purpose if an early start is made on building experiments for other systems.

US-Euratom 'agreement'

THE ROSY PICTURE that was painted with the signing of the agreement between the United States and Euratom two years ago under which US help was to be given in a programme to install 1000 MW of nuclear power capacity by 1965 has long since been regarded as too optimistic. It was to be expected that with the cheapening in cost of fossil fuels and the drop in capital costs of conventional power stations, some adjustments to the programme would have to be made. What was not expected, and is to be regretted, is that talks going on behind the scenes on amendments should have led to a break in the previously good relations between the two parties. Understandably, the United States is disappointed in the failure of the first phase of the Euratom programme with only one station, Senn, being built; but its suggestion that the Euratom research programme should be curtailed is surely cutting the heart out of the organisation. It was this that led to Euratom making a stand and saying that it would not agree to issue invitations for the second phase of the programme (see *Worldview*, May) unless the research programme was allowed to continue unfettered. It is unfortunate, too, that this disagreement should have been followed by an 'investigation' by Mr. Robert McKinney. It is to be hoped that this disagreement will be a passing phase and that both bodies will come together and work out some compromise which will not jeopardize the research programme and will lead to the issuing of the invitations scheduled for this summer for two power projects before 1965.

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Worldview

the month in atomic energy

EUROPE

Euratom-US split widens

London Differences of opinion between the United States and Euratom, which have been growing more marked in recent months, are now acute; according to Italian press reports they may lead to a recommendation that the US-Euratom co-operation agreement be cancelled.

The most recent division has centred around a conference on Euratom research work held at Bellagio, Italy, at which apparently no Euratom representative was invited. The meeting was sponsored by the Rockefeller Foundation and called by Mr. Robert McKinney, former US representative to the International Atomic Energy Agency, who is now investigating the European nuclear power programme, including Euratom, for the US Joint Congressional Committee on Atomic Energy.

Invitations to the meeting were sent to heads of research in all the European countries. France and Belgium were represented but not the other Euratom members. Other countries represented included Sweden, Switzerland, Canada, Britain and the United States.

The meeting's agenda was not disclosed but according to press reports in Rome, Professor Felice Ippolito, general secretary of the Italian Committee for Nuclear Research, is reported as saying that one of the topics was the application and implementation of the US-Euratom agreement. The reports add that it was the Professor's opinion that it might be conceivable that following Mr. McKinney's tour of Europe, a proposal might be put forward to the US Congress for the cancellation of the Euratom agreement due to difficulties in implementing it.

These reports follow the recent criticism by the Joint Congressional Committee of the Euratom programme which it described as a failure so far. Discussing the US Atomic Energy Commission's budget for the coming year, the Committee said that one of the negative aspects so far had been 'the failure of the Euratom programme to come up with a single project to meet its 1963 goal of one million kilowatts except for the Italian Senn project which was organized outside the Euratom programme. Testimony indicated that there were still prospects for one or two proposals under the 1965 goal.'

Open disagreement between the US and Euratom was admitted in April (see *Worldview*, May) when the European agency said they had told the US authorities that unless the research programme was made more flexible, it could not agree to issue invitations for the second part of the power reactor programme. This split apparently arose over a US decision to financially restrict joint research efforts until projects additional to Senn were put forward.

Second Windscale separation plant started

London Work has started on the building of a second primary separation plant at the UK Atomic Energy Authority's Windscale works in Cumberland. It will take three years to complete. (See article on page 92 of this issue.)

The contract for the work has been awarded to the Mitchell Construction Company Limited of Peterborough and covers the main civil engineering and building works for the plant which will service fuel elements received from the new civil nuclear power stations.

Mitchell's have also been awarded a £145,000 comprehensive contract by the AEA for the supply and erection of civil engineering work, steam generation plant, buildings, an oil tank farm and ancillary equipment for Windscale. The contract is due for completion in October this year.

• **United Kingdom** The estimated cost of building the advanced gas-cooled reactor at Windscale is about £9 million, the House of Commons was told recently.

TRAWSFYNYDD PROJECT PROGRESSES This view of the 500 MW nuclear power station under construction at Trawsfynydd in North Wales by Atomic Power Constructions Ltd shows reactor No. 1 in the foreground. In the background (centre) is the site of the turbine hall and on the right, reactor No. 2. The station is the first of the CEGB's to be sited inland

Credit terms will decide Spanish reactor purchases

London Credit terms and their effect on the sales of British reactors were discussed by Sr. Jaime Mac-Veigh, director of the Spanish concern, Centrales Nucleares S.A. (Censua) here recently. Sr. Mac-Veigh was one of 16 representatives of Spanish industry who visited the United Kingdom at the end of April as guests of the Federation of British Industries.

Censua has fixed a joint programme for nuclear power until the early 1970's under which three 250 MW nuclear power stations are scheduled. The first contracts are to be let in 1963.

'The award of these contracts will hinge on credit terms', Sr. Mac-Veigh told NUCLEAR POWER. Credit terms for a period of six to seven years were not any good but if they could be extended to about 15 years it would be far more attractive. Spain was not a rich country and consequently she had to seek the best terms available, he added.

On the programme Censua has mapped out, Sr. Mac-Veigh said it was envisaged that a 250 MW nuclear power station for the Madrid load-centre should go critical by the end of 1968 and be on full load from the beginning of 1970 onwards. The second station at Seville should go critical by the end of 1970 and be on full load from the beginning of 1972 and the third unit, again at Madrid, should go critical at the end of 1972 and on full load two years later.

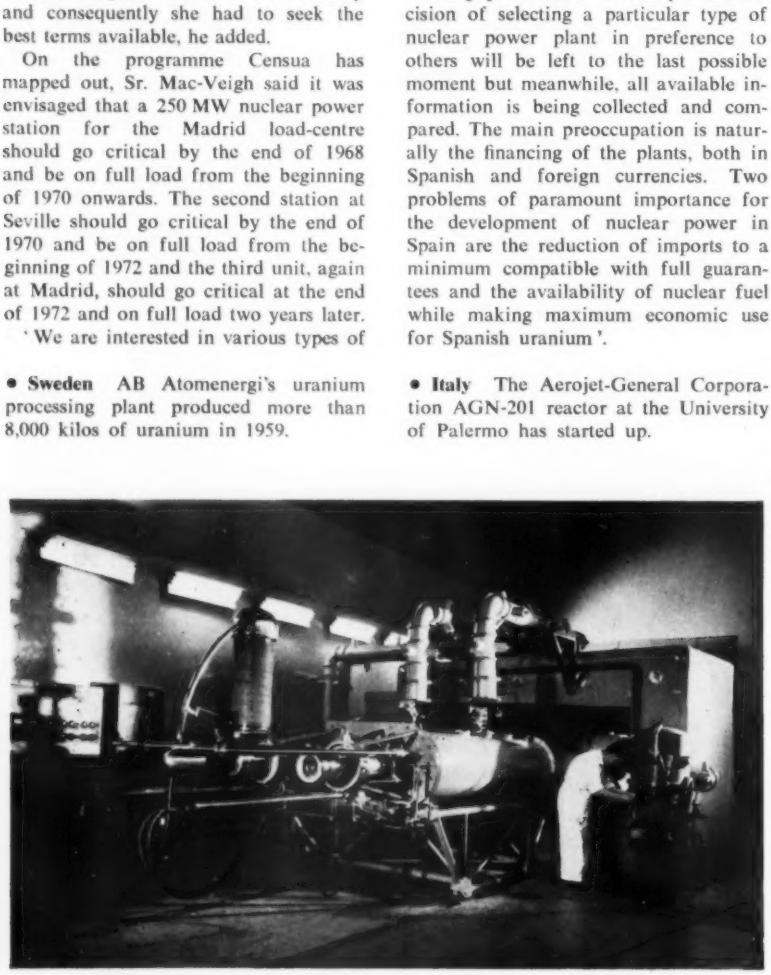
'We are interested in various types of reactors,' Sr. Mac-Veigh added. 'The Magnox type, of course, has operating experience but we have also been following the progress and discussion over the advanced gas-cooled reactor and are interested in the natural uranium, heavy water organic moderated type but there again there is no operating experience to go by'.

In a recent paper presented in the United States, Sr. Mac-Veigh discussed the three nuclear power plants. He said that since there would only be two year intervals between the commissioning of the three plants, there seemed to be a great advantage in considering them, as much as possible, as parts of a single large project to be developed from 1963 to 1972. There was also a possibility that nuclear power would be required at Valencia after the end of 1974.

His paper added: 'The important decision of selecting a particular type of nuclear power plant in preference to others will be left to the last possible moment but meanwhile, all available information is being collected and compared. The main preoccupation is naturally the financing of the plants, both in Spanish and foreign currencies. Two problems of paramount importance for the development of nuclear power in Spain are the reduction of imports to a minimum compatible with full guarantees and the availability of nuclear fuel while making maximum economic use for Spanish uranium'.

• **Sweden** AB Atomenergi's uranium processing plant produced more than 8,000 kilos of uranium in 1959.

• **Italy** The Aerojet-General Corporation AGN-201 reactor at the University of Palermo has started up.



CZECH CYCLOTRON A recent picture of the Czechoslovak cyclotron at the Nuclear Research Institute at Rez, near Prague. It accelerates deuterons to a speed of 12·5 million electron-volts and alpha particles up to 25 million electron-volts.
Czechoslovak News Agency

DRAGON PROJECT INAUGURATED Dr. Sigvard Eklund, chairman of the OEEC Dragon project, performs the ceremony to mark the start of work on the high temperature gas-cooled reactor project at Winfrith Heath, Dorset.

Dragon project contract award

London The main contract for the reactor building for the Dragon project at Winfrith Heath, Dorset, is expected to be awarded by the end of June, NUCLEAR POWER understands. The contract for the foundation work has been awarded to Turrif Construction Corporation of Warwick, who had completed four weeks work when the formal Dragon inauguration ceremony took place last month. This work is expected to be completed by the middle of July.

Following the inauguration ceremony came the expected announcement (see *Worldview*, April, 1960) that the US and the 12 OEEC Dragon project members had agreed to exchange information on high temperature gas-cooled reactors (HTGCR). This relates to the 20 MW Dragon project and to the 40 MW (electrical) HTGCR to be built by the Philadelphia Electric Company. Information from the OEEC project will be made available to US industry.

French–Soviet exchange

Paris The recent co-operation agreement signed between France and the Soviet Union, covering 1960–61, provides for the exchange of scientists, Franco-Soviet seminars in France in 1960 and in the Soviet Union the following year, exchange of information on high energy physics, theoretical and experimental nuclear physics and controlled fusion problems.

• **Bulgaria** Bulgaria and Yugoslavia are to exchange scientists and experts under a technical co-operation agreement signed recently.

Berkeley and Bradwell costs soar

London The cost of building the first two commercial nuclear power stations in the United Kingdom—Berkeley and Bradwell—has risen steeply from original estimates, according to calculations by the Central Electricity Generating Board which will shortly be considered at a meeting. In a talk with NUCLEAR POWER after the recent press reception for the approaching British Power Convention, Mr. C. R. King, Chairman of the Electricity Council, said that before the stations actually come into operation the cost will have risen to at least £160 a kilowatt.

This is a considerable rise from the figures previously allowed for these stations, and casts doubts on the accuracy of recent forecasts published in the technical and general press for the later nuclear power plants.

Some of the increase will of course be due to the design modifications which have taken place during construction (NUCLEAR POWER, April, p 146), and may therefore presumably not be reflected in later plants, but it is reported that other original estimates—that for civil engineering work for example—were also considerably lower than the actual cost.

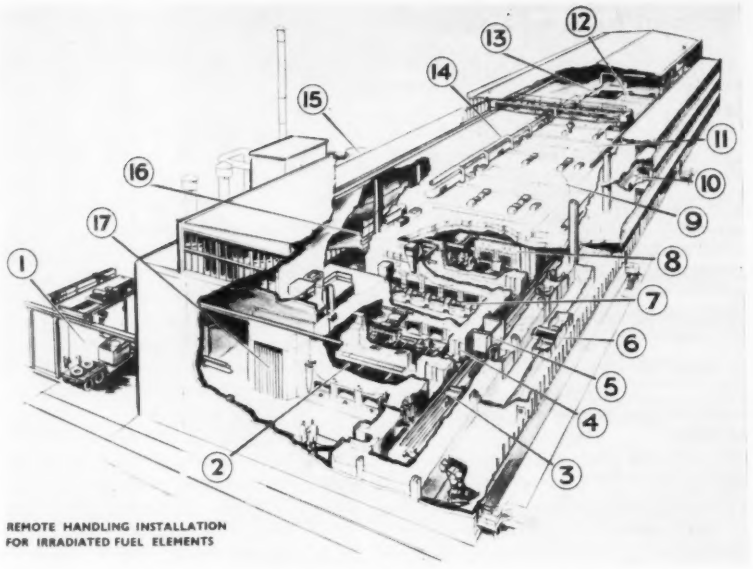
Oldbury to use Magnox canning

London The possibility that a further three sites on the River Severn, Gloucestershire, might be required for nuclear power stations was brought out at the recent inquiry into the Central Electricity Generating Board's proposal to build a 500 MW nuclear power station at Oldbury-upon-Severn.

Mr. S. B. Cooke, for the Board, told the inquiry that if a solution were found to the problem of cooling water at the three sites, which were within a five mile radius, it might be that they would be required. He added that the original capacity of the station at Oldbury was 1000 MW; it was now proposed that it should be 500 MW as a first stage but the Board hoped to extend it to the maximum in due course.

There are to be two reactor buildings and a building to house turbo-generators. It is understood that magnox canning will be used for the fuel elements and that construction is expected to take 4½ years. If authorized, Oldbury will be the seventh station in the government's programme of 12 nuclear generating stations.

Objectors included the Council for the Preservation of Rural England; the Severn Estuary Fisherman's Association and the Gloucestershire branch of the National Farmers' Union.



REMOTE HANDLING INSTALLATION FOR IRRADIATED FUEL ELEMENTS

WINDSCALE FUEL ELEMENT PLANT An artist's impression of the remote handling installations being built at Windscale by E. G. Irwin and Partners Ltd. The key to the number items is: (1) flask reception area; (2) element storage; (3) tray transporter; (4) de-bottling and trayloading cave; (5) shielded transporter; (6) maintenance access change rooms; (7) machine control consoles; (8) element examination cave; (9) decanning cave; (10) main control room; (11) fuel rod cutting and sampling; (12) decontamination cave; (13) maintenance workshop; (14) ventilation system; (15) iodine scrubber installation and (16) switchgear gallery; (17) flask entry.

Organic-moderated power reactor for Italy

Rome The Italian National Committee for Nuclear Research has sanctioned the building of a medium-sized organic-moderated power reactor in Central/Northern Italy. The site is still to be decided upon but construction, to be undertaken by the Societa Sorina, is scheduled for completion by 1964. Capacity of the reactor, which will be designed by the Societa Agip Nucleare, is envisaged at 30 thermal MW.

The reactor will be used to study the uranium-thorium fuel cycle programme which the Committee is conducting with Allis-Chalmers of the United States. It entails joint-research development work to demonstrate the feasibility and to determine the economics of a thorium-uranium 233 fuel cycle for power reactor systems. Work will include the design, construction and operation of an integrated thorium-uranium fuel element reprocessing and remote fabrication pilot plant to be located in Italy. It will also cover an evaluation of the application of thorium fuel to existing Italian power reactor systems.

A study is to be made of the most favourable reactor type for exploitation and, based on the results of these studies, the conceptual design of a large, central station reactor will be prepared.

UK Bill on radioactive material

London The Radioactive Substances Bill which has been given an unopposed third reading in the House of Commons and only needs Royal Assent to become law, is to be brought into operation as soon as possible. The Bill regulates the keeping and use of radioactive material and controls the disposal and accumulation of radioactive waste.

Mr. Henry Brooke, Minister of Housing and Local Government, told the Commons that no time would be lost over bringing the bill into operation. The Government regarded its requirements as the minimum. They wanted to improve on them.

• **W. Germany** Metallgesellschaft A.G. of Frankfurt is to import 40 lb of depleted uranium metal from W. R. Grace and Company of New York for research work.

• **United Kingdom** A total of 35,000 shipments of radioisotopes valued at £1 million were made by the UKAEA during the 1959 financial year.

• **Yugoslavia** A Yugoslav Nuclear Energy Commission delegation has visited Moscow to discuss cooperation in the peaceful uses of nuclear energy.

• **Sweden** A concessions system of exploitation of uranium deposits rather than the present claims system is proposed by the Swedish Minister of Justice.

Euratom likes fast reactors

Brussels Particular interest in fast reactors and the conclusion that by 1980 Euratom countries could have at their disposal 250 nuclear power plants with a total output of 40,000 MW are expressed in Euratom's third annual report. It also points out that delay in the transfer to Euratom of the Italian Nuclear Research Centre at Ispra is tending to jeopardize its research programme.

On the fast reactor, the report says Euratom is planning to construct a critical assembly in one of the Community countries, the study and operation of which will provide valuable data on the subject of fast reactor neutron physics and control.

It estimated that electricity requirements of the Community countries would be about 950,000 million kWh in 1980 and that annual per capita electricity consumption in the Community in the same year would be 5,000 kWh. This would be scarcely 10% greater than the corresponding 1959 figure for the United States and much lower than the Soviet target of 8,500 kWh for 1980.

Using these figures, Euratom experts conclude that by 1980 member countries could have at their disposal a net installed nuclear power of 40,000 MW. In other words, they could possess 250 nuclear power plants with a power of 150 MW. The report adds that even an appreciable reduction in the figure given would 'leave such wide scope for development in the nuclear field that it would appear advisable to take immediate steps for the encouragement of the necessary financial and industrial effort. . . .'

One obstacle in the way of immediate development of nuclear power plants was that the cost of nuclear electricity was much higher than that produced by conventional plant. 'Far from becoming discouraged by this stumbling block manufacturers and electricity producers must be ready to make certain temporary sacrifices and to commit themselves resolutely to carrying out a minimum nuclear power-plant programme', says the report.

Other points from the report are:

Nuclear propulsion: In Europe there are eleven projects for nuclear ships. In order to prevent duplication and to bring about a concerted effort, Euratom is endeavouring to co-ordinate research and work done on actual projects.

Training: A Euratom Interim Committee has submitted its report on the setting up of a European University; the development of European Institutes of Higher Education; the co-ordination of university curricula and an extended system for degree equivalence.

Research: Negotiations are in progress for setting up a general purpose joint research establishment at the Reactor Centrum Nederland. Research done there will initially draw on possibilities offered by a materials testing reactor now being built.

Other negotiations are going on for the building at the Karlsruhe Nuclear Research Centre of a joint centre establishment to specialize in the use and study of plutonium and the development of plutonium-based fuel elements.

Industrial: Studies relating to the possible construction of a heavy water moderated organic-cooled natural uranium reactor are being carried out.

A three-year agreement with the Dutch firm, N.V. Tot Keuring van Electrotechnische Materialen for the study and construction of a homogeneous suspension reactor has been concluded.

Fusion: A contract of association in this field has been concluded with the French Atomic Energy Commission (CEA). A second is being negotiated with the Max Planck Institute fur Physik und Astrophysik in Munich.

Safety: A model irradiation card for nuclear workers has been designed and has been accepted by the control services of member states and is beginning to be used in large nuclear installations.

• **Italy** Experiments are now being carried out with the Enrico Fermi Nuclear Studies Centre's 50 kW training reactor which recently went critical.

• **UNO** European specialists met in Paris at the end of April to discuss the microbiology of irradiated foods.

• **United Kingdom** Euratom and UK experts discussed the UK advanced gas-cooled reactor system and complementary European work recently.

• **Italy** Fiat SpA of Torino is to import five lb of natural uranium dioxide and 10 lb of depleted uranium oxide from Luigi Serra Incorporated of New York for research and development on UO_2 sintering.

• **France** The French Line's new liner, the 70,000 gross ton *France*, has a hull specially strengthened to take an atomic power unit at some later date.

• **Yugoslavia** A US technical mission has discussed how Yugoslavia and the USA can channel their co-operative activities through the International Atomic Energy Agency.

German tanker project dropped

Hamburg According to the West German Transport Ministry, a project to equip a 16,000 ton tanker, the Esso Bolivar, with a marine reactor is not to be carried out because it will be too costly. The official pointed out that there were still in existence plans to build a 'test' vessel and equip it with several types of reactor in order to carry out research and tests.

UK isotope trading shows loss

London Figures for isotope trading by the UK Atomic Energy Authority are expected to show a future surplus, though there was a loss in 1958–59, according to the report of the Comptroller and Auditor-General, Sir Edmund Compton, on the Authority's balance sheet published this month.

The statement for 1958–59, prepared before the Authority decided to reorganize selling arrangements, showed a deficiency on isotope trading of about £250,000 on the year; an accumulated deficiency of about £500,000 and unamortized costs of research amounting to some £600,000.

Prices were being reviewed regularly but no further changes were likely before March 31, 1960, the Authority said when asked in November 1959 what progress was being made. They expected that as a result of measures taken in the past year, isotope trading would show a surplus for the future. The Authority considered that isotope trading to March 31, 1959, had been adversely affected by the cost of basic research.

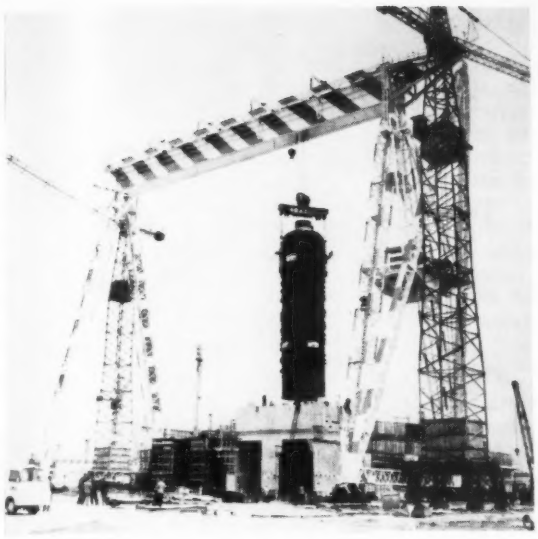
The report showed that the net cost of operations of the AEA for the year ended March 31, 1959, was £43,810,939 against £42,433,428 in 1958.

W. German firm to build gas-cooled reactors—U.S. style

Bonn The design and manufacture in Germany of full-scale versions of General Dynamics Corporation's high temperature, gas-cooled reactor (HTGR) for central power generation is provided for in a long-term licence agreement between the American firm and Gutehoffnungshutte Sterkrade A.G.

The agreement gives the German concern exclusive manufacturing and sales rights in Germany and also includes the Triga research reactor made by the American concern. The HTGR itself is a high performance, compact reactor. It is graphite moderated and helium cooled and uses a new type of graphite-clad homogeneous fuel elements which also act as moderators. A 40-MW prototype is being built by General Dynamics in the United States and will be completed in 1963.

Gutehoffnungshutte is a leading German engineering and manufacturing concern. Its nuclear products include heavy components for research and power reactors now being built in Germany.



PROGRESS AT LATINA Latest pictures of the 200 MW Latina nuclear power station being built by the Nuclear Power Plant Company of Knutsford and Agip Nucleare of San Donato Milanese. It is due to be completed in 1962, four years after work started. The top picture (right) shows a general view of the station and the picture on the left shows the Goliath crane installing the first boiler in the reactor.

• **United Kingdom** Mitchell Engineering Ltd's representative in Argentina, Mr. Myron Wydett, is continuing negotiations for the installation of a 20 MW boiling water reactor near Buenos Aires.

• **Italy** The Italian firm Selni is considering a site at Trino Vercellese, Piedmont in addition to one at Vallegrande on the Italian Riviera for its nuclear power station.

• **Sweden** An application to the Swedish Government for concessions to explore uranium, thorium and beryllium deposits in north Sweden has been made by Svenska Cellulosa AB.

• **W. Germany** Bavaria is planning to have a centre for the collection of radioactive waste.

New UK research establishment is being built

London Construction work on the UK Atomic Energy Authority's new research establishment at Culham, Oxfordshire, has now started. The building contract for the first phase of construction has been placed with M. J. Gleeson (Contractors) Ltd.

Culham is to be developed as a laboratory for research into controlled thermonuclear reactions and plasma physics. The first buildings are to house facilities for the International Current Stability Experiment.

Meanwhile, experimental work using Zeta, the Zero Energy Thermonuclear Assembly at Harwell, is expected to be completed by the end of this year. A UKAEA spokesman said it had a scheduled programme up to the end of this year but nothing further had yet been planned.

Nuclear propulsion mission tours Europe

Washington A European Nuclear Energy Agency (ENEA) mission is to tour Europe to gain information on various national nuclear propulsion programmes. It will also discuss the possible means by which an international collaborative effort can be initiated and will report to the ENEA during the early summer of this year.

Mr. L. W. Boxer, scientific and technical Division, ENEA, revealed this during the course of a conference on the role of nuclear propulsion in merchant shipping organized by the Atomic Industrial Forum in the United States. The mission is to be led by Dr. S. Eklund.

Mr. Boxer said that the overall picture of nuclear propulsion programmes in OEEC countries was that though not one was firmly committed to a particular course of development, many were showing interest in following a similar line of policy. It appeared the situation could lead to more collaboration and it was evident that some pooling of resources in a common effort between countries was desirable and indeed necessary.

For Euratom, M. Eduard Von Geldern, Director General of Industrial and Commercial Affairs, said that as far as technical problems were concerned, Euratom 'will probably sign contracts with various industrial groups or national research centres in its member states and do some research work in its own common research centre'.

Mr. A. Ohya, vice-chairman of the Japan Atomic Industrial Forum, reporting on the Japan Nuclear Ship Mission which visited Europe and the US late last year, said that his mission took the view that nuclear ships would become competitive in seven to ten years time, taking into consideration the current level of research and development activities in various countries.

• **Switzerland** Thermatom AG and Energie Nucleaire SA are to join together to build an experimental reactor in the western district of Lucens.

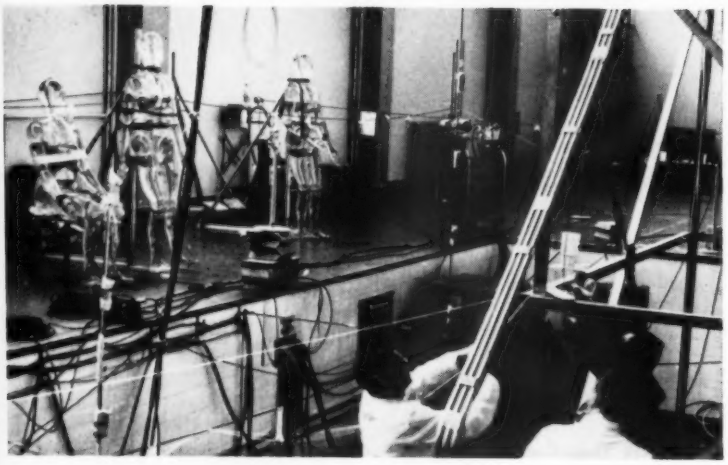
Fault in Norwegian reactor

Oslo A leak discovered in the heavy water tank of the experimental 500 kW boiling water reactor at the Kjeller research centre, near Oslo, recently, caused production of radioisotopes to be affected. Before the leak could be repaired, technicians had to remove fuel charges from the reactor. Isotopes from Britain were imported to make good the loss of production.

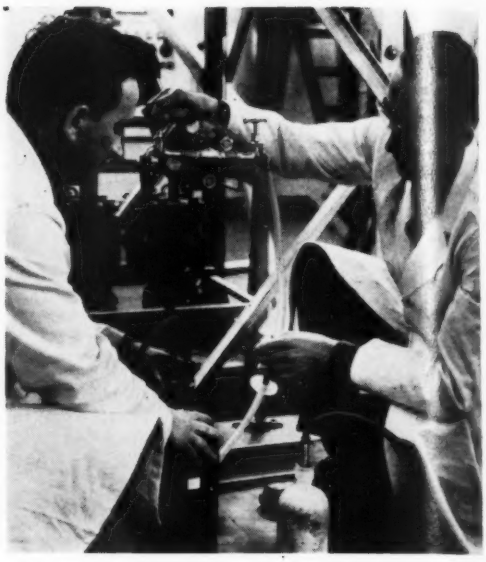
W. German power programme

Bonn Under the latest extended nuclear programme of the West German Atomics Ministry, which has now been approved by the West German Atomic Energy Commission, provision is made for the construction of high performance reactor systems of 100 MW or more; the development and construction of medium performance types of 20 to 50 MW and of marine propulsion systems developing 10,000 to 20,000 shaft horsepower.

The Commission also asked the Atomics Minister, Professor Balke, to continue with his Ministry's policy on the development of nuclear technology and the setting up of competitive nuclear installations.



REACTOR ACCIDENT RE-ENACTED The 1958 reactor accident in Yugoslavia when one scientist was killed and five others were subjected to serious radiation exposure during a brief uncontrolled run of the Vinca Zero Power Reactor at the Boris Kidric Institute was re-enacted recently by the International Atomic Energy Agency. An international team of scientists took part and the picture above shows the French team finishing the preparations for the experiment. The four plastic dummies, filled with salt solution, were flown over from Oak Ridge, Tennessee



Members of the French team fill the research reactor tank with heavy water from Harwell before the experiment to determine how much radiation each scientist received during the 1958 Yugoslav reactor accident.

OVERSEAS

Russian electrification plans omit nuclear power

Moscow No mention is made of plans for nuclear power stations in estimates made by the USSR Ministry of Power Construction that 100% electrification of the Soviet Union can be achieved within the next 15–20 years.

Details are concerned with the building of big hydro-electric stations where it is most economical to construct them and with locating thermal power stations where there are fuel desposits, with power being transmitted by long-distance transmission lines.

At present 40 large thermal power stations and a number of large hydro-power stations are being built in the Soviet Union. In addition, about 60 thermal stations are being reconstructed. It is also planned to build 17 large gas-fuelled power stations during the current seven-year period.

According to the Ministry, annual power generation in the Soviet Union will be raised to more than 500,000 million kilowatt hours under the Seven-year Plan and it is planned to put into operation power plants with a total capacity of 60 million kilowatts.

Soviet planners expect that by 1970, the USSR's annual power output will have reached 900,000 million kilowatt hours, and that between 1965 and 1970, new power plants totalling 75 million kilowatts will be put into operation.

South Africa builds uranium processing plant

Pretoria A pilot plant to produce nuclear-grade uranium metal and compounds suitable for nuclear fuels is to be built at Johannesburg and is expected to be in operation before 1961.

Dr. A. J. A. Roux, research director of the South African Atomic Energy Board, said the plant would be capable of producing up to one hundred tons of metal a year and would enable investigations to be made into techniques for the processing of nuclear grade uranium.

New thermonuclear assembly for US university

Washington A new experimental thermonuclear assembly known as Alice, to be put into operation early next year, is being built for the Lawrence Radiation Laboratory operated by the University of California. This report was made known at the spring meeting of the American Physical Society when preliminary experiments with a smaller device, known as 'little Alice' were said to have been promising.

Alice is the name for Adiabatic Low-energy Injection Capture Experiment.

Radiation level rises at Oak Ridge building

Oak Ridge A slight rise in the radiation level in the Solid States Building at the US AEC's Oak Ridge National Laboratory recently resulted in the evacuation of the building. Radiation monitors sounded when a change in the internal air flow in the building carried radioactive particles, consisting of graphite contaminated largely with cerium and strontium, from a process cell into other areas of the building.

Work on US organic moderated reactor continues

Washington Fluor Corporation is to undertake modifications to the Organic Moderated Reactor Experiment (OMRE) to extend its operating usefulness over the next few years. The OMRE is situated at the National Testing Station near Idaho Falls, Idaho, and is operated for the USAEC by Atomics International. It was originally designed to test the feasibility of a reactor cooled and moderated by an organic fluid. Its successful operation has indicated a need to continue engineering development of the concept.

• **Japan** The research centre at Tokai Mura has started the production of radioisotopes for sale in southeast Asia.

• **IAEA** A final draft on minimum international standards for civil liability for nuclear damage is to be published this autumn.

Dresden reactor feeds electricity into grid

New York Electricity generated by the 180,000 kWe Dresden boiling water reactor in Illinois is now being fed into the state's electricity system. First output from the plant reached 64,000 kWe but production rate will be increased gradually with testing being done at various levels.

The reactor went critical in October 1959 with 28 uranium fuel assemblies loaded. Since then testing operations have been conducted as the core was loaded to the 448 fuel assemblies for the initial stage of operation. It will be brought up to half-power and then shut down to check performance data. Gradual steps will then be taken to bring it up to full power, with the US General Electric-Commonwealth Edison reactor expected to be in full operation this summer.

The reactor is the first privately-financed boiling water reactor power plant to come into operation and feeds steam from the core directly to the turbines. Construction work has been rapid, work on building the reactor having started three years ago.

US pressurized water reactor proposals unacceptable

Oak Ridge None of five proposals submitted to the USAEC for operating a 22 MW pressurized water reactor with a fossil-fuelled superheater have proved acceptable. However, the AEC announced that it is allowing two proposers to suggest alternative site to those originally proposed by them.

The AEC is designing the reactor and plans to build it under its Power Demonstration Reactor Programme.

Isotopes cut Soviet coal costs

Moscow A technique for estimating the thickness of coal seams by radiation has been introduced on a wide scale into the Soviet coal industry. The method, it is understood, cuts costs and halves the time taken by previous methods. This was revealed during a recent conference on the uses of radioisotopes and radiation held at Riga, Latvia, which was held in conjunction with an Atoms for Peace exhibition.

Japan builds three new research reactors

Washington Japan is to be provided with approximately 100 kilograms of uranium enriched up to 20% with U-235 for three new research reactors under an agreement signed between her and the United States. The reactors, to be built at the Japan Atomic Energy Research Institute at Tokai Mura, are a semi-homogeneous critical facility, an aqueous homogeneous critical facility and a fast breeder exponential experiment.

The signing of the three new leases for fuel brings to five the number of Japanese research reactors that will be fuelled with nuclear material supplied by the United States.

• **United States** Westinghouse Electric Corporation has received a US Navy contract for the design, development and production of nuclear propulsion equipmen for three submarines.

• **South Africa** Export of prescribed materials under the Atomic Energy Act were valued at £4,095,804 in March 1960 compared with £3,865,220 in March 1959.

• **Canada** Lorado Uranium Mines has sold its uranium contract to Eldorado Mining and Refining.

• **Pakistan** A 'uranium ore type' has been reported found in the Indus Valley.

Japanese hold symposium

Tokyo A symposium on the long-term development of nuclear power held here recently was attended by 30 leading Japanese scientists. It was sponsored by the Japan Council of Science and discussions centred on such problems as policies for nuclear power development projects and reactor safety.

Australia keeps close watch on uranium market

Canberra The Australian Government is keeping a close watch on developments in the uranium mining industry with a view to protecting home industry against a world market decline. This was disclosed recently by a Government spokesman here and followed up a statement some time ago by Senator Spooner, Minister for National Development, that the Government wanted to keep its uranium mining industry alive and active in face of the lull in demand which could be foreseen when current contracts expired.

• **India** The Indian Government is reported to have offered rewards to finders of new deposits of uranium ore.

• **Japan** A high grade uranium ore deposit has been found in Tottori Prefecture on the north west coast of Japan.

• **United States** The USAEC issued 12 new contracts for unclassified physical research in the first two months of this year.

Japanese company plans own nuclear-powered ship

Sydney During his recent tour of Australia and New Zealand with three other members of his firm, Mr. T. Shaurai, president of the Mitsubshi Company of Japan, disclosed that work on an experimental nuclear-powered ship would begin in the next two years (see *Worldview*, January). It would be ready in 10 years. Mr. Shaurai also said that Japanese plans for developing plant for producing nuclear power were proceeding satisfactorily.

Britain is second largest buyer of US heavy water

Washington Britain was the second largest buyer of heavy water from the United States in the period 1955–59 according to figures released here. The total amount sold in that time was 790,534 lb, of which the leading purchasers were Canada with 278,000 lb; Britain with 110,020 lb; W. Germany with 89,000 lb; France with 66,002 lb and Sweden with 57,000 lb.

Few proposals for advanced US boiling water reactor

Washington The USAEC has received only two proposals from publicly-owned utilities for operating a prototype 50 MW boiling water reactor of advanced design and four proposals from reactor manufacturers to provide the reactor for the plant. The AEC also said there had been no response to a similar invitation issued last December for the design, construction and operation of a prototype organic-cooled reactor.

Graphite contract for US gas-cooled reactor

Washington A contract to provide 120 machined graphite columns for the core of the experimental gas-cooled reactor (EGCR) under construction at Oak Ridge, has been awarded to National Carbon Company, a division of the Union Carbide Corporation, the US Atomic Energy Commission has announced.

The bulk of the columns will be approximately 16 inches square and 20 feet long with the design providing necessary channels for fuel assemblies, controls rods and other instrumentation and eight experimental loops for research and development programmes. Only four loop spaces are expected to be used when the reactor first starts up. Shipping weight of the graphite to be provided is 379,000 lb.

The EGCR is designed as a combined experimental and electrical power-producing unit and will use slightly enriched uranium dioxide as fuel, helium as the coolant and graphite as the moderator and reflector material. Construction started in August 1959 and is expected to be completed late in 1962.

Construction work has started on the new Windscale separation plant

Reprocessing fuel from the civil reactors

by K. SADDINGTON, M.Sc., F.R.I.C.

Head of Laboratories, Research and Development Branch, UKAEA, Development and Engineering Group, Windscale

WHEN fission products are separated from the valuable uranium and plutonium isotopes it is possible to keep these together and to refabricate them for subsequent use as a mixed fuel; however, current large-scale practice aims at separating them from one another. The uranium is then re-enriched with further U-235 and re-used in the same (thermal) reactor system. The separated plutonium is available for use in advanced reactor systems or for military purposes.

Table I gives the composition of 1 tonne of natural uranium with a notional irradiation dosage of 1000 MWd/ton and after a cooling period of 100 days during which the short-lived fission products are allowed to decay.

Depending on the future use and methods of refabrication of the separated fissionable materials, Decontamination Factors of them from the fission products and from one another of the order 10^6–10^8 are required. (The Decontamination Factor, D.F., is defined as the ratio of the concentrations of the fission products in the valuable matrix material before and after processing.)

PROCESS SELECTION

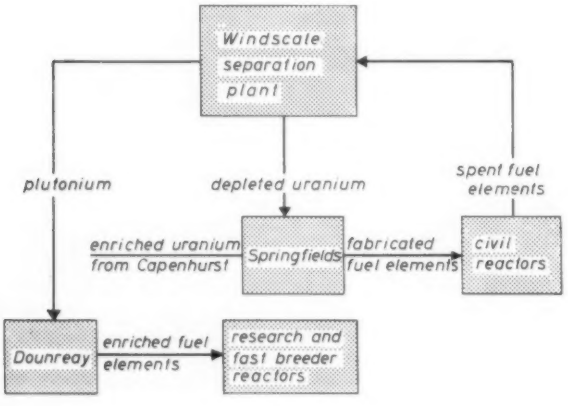
Of the various methods developed for the chemical treatment of irradiated fuels, only those based on solvent extraction techniques applied after dissolution of the fuel in acid are in current use on a production scale. Of these, the oldest established processes involve the use of hexone (methyl-isobutyl ketone) at Hanford in the United States and 'Butex' ($\beta\beta'$ dibutoxy di-ethyl ether) at Windscale.

Originally the economic factor in the choice of a suitable solvent (and process) was secondary to the problem of finding a solvent which, as well as having favourable differential extraction and back-extraction properties, was acceptable for plant use on other grounds. These are chemical and radiation stability, non-inflammability and -volatility, immiscibility with, and ease of separation from the aqueous phase—this last property depending on the interfacial tension and density differences between the components. Different solvents meet these requirements to varying extents but hexone and butex at the time (pre-1950) appeared to have optimum characteristics.

With greater emphasis on the use of nuclear energy for power rather than for military purposes there has been a need for a more economical solvent. For this reason, as well as for its superiority in other directions, tributyl phosphate (TBP) is currently favoured as the solvent for large-scale chemical processing. As such it is already in use at Hanford, USA, and Marcoule, France, and has been chosen for the process currently under development in the UK for the treatment of spent civil reactor fuels.

PROPERTIES OF TRIBUTYL PHOSPHATE

Tributyl phosphate is extremely selective and versatile. Like butex and hexone it can be used in continuous extraction processes in which nitric acid is the aqueous phase and, unlike hexone, does not require the addition of salting out agents, other than the nitric acid itself, to obtain efficient extraction. The pure solvent suffers from the disadvantages of a high viscosity (3·41 centipoises at 25°C)



WHY REPROCESSING IS NECESSARY

1. Radiation damage in solid fuel elements leads to loss of mechanical strength, physical distortion and the possibility of can failure. The fuel must therefore be removed before these effects endanger reactor operation.
2. When fission products build up the fuel must be discharged periodically to remove them and maintain the neutron economy of the system.
3. The discharged fuel will contain unused original fissionable material, e.g. U-235, as well as some new fissionable material formed in the reactor, e.g. Pu-239. For the power programme to be economic these materials have to be recovered, free from fission products contamination, for refabrication into fuel elements with metallurgical and mechanical properties equal to those of new material.

and a density (0·973 at 20°C) similar to that of water so that phase separation is difficult. These drawbacks are overcome by diluting the pure solvent with an inert material such as kerosene or other cheap hydrocarbon to give a 20–40% solution. The consequent loss of extraction power is not usually a drawback but the reduced solubility in the diluted solvent of the actinide—TBP complexes imposes limitations on the solute concentrations so as to avoid the formation of a third phase which would complicate contactor operations. These limitations are normally of secondary importance. The diluted solvent is not only much cheaper than butex but is also much less soluble in water than either butex or hexone so that solvent losses are markedly reduced, by as much as 25 fold for a 20% TBP/kerosene solution compared with butex. A further big advantage is that by the use of TBP the decontamination factors from fission product activity are much higher at each stage of the process, so that the overall size of the extraction plant is considerably reduced with consequent cost savings. In addition, a greater fraction of the total fission product decontamination factor is achieved at the first extraction stage and the heaviest concrete shielding is limited to this stage only.

The degree of dilution of TBP by kerosene must be optimized to achieve high extraction efficiencies for the actinides and so allow economical solvent utilization, good decontamination from fission products, especially in the early stages, and rapid and efficient settling of the mixed phases. For civil-type reactor fuels the choice is usually between 20% and 40% TBP in hydrocarbon, the lower values leading to easier phase separation because of greater density differences while the higher values allow lower solvent-aqueous ratios which lead to solvent economy.

FEED PREPARATION

In common with current practice in the UK, mechanical decladding of the civil reactor fuel elements under water by remote control is planned. However, the present system by which the rod is forced by a hydraulic ram through a die which will not allow passage of the can will be replaced by a slitting and ploughing technique. The fuel elements pass lengthwise through three cutting wheels which deeply score the cans without cutting into the uranium. A follow-up plough forces the cans off the fuel in the form of three long strips which are chopped and sent to solid waste storage.

OUTLINE

The new Windscale chemical separation process for the treatment of spent civil reactor fuel rods differs markedly from the present process which has been operated successfully for the past eight years. This method was based on solvent extraction techniques in packed columns using butex solvent. The new process is also based on solvent extraction but uses tributyl phosphate diluted with an inert hydrocarbon in horizontal box-contractors. It is suitable for treating the more highly irradiated civil reactor fuels and has an efficiency superior to that of the butex process. Capital and operating costs are substantially lower.

Again following current practice, the fuel will be dissolved continuously in nitric acid by the so-called 'fumeless' process, which conserves acid, to produce a uranyl nitrate solution approximately 3N in nitric acid and containing 300–400 grams uranium per litre. After conditioning, this solution is continuously fed to the solvent extraction contactors. Development work was directed towards providing a remotely operated centrifuge for feed clarification from sludge material but encouraging results obtained without this made it unnecessary.

DEVELOPMENT OF THE CHEMICAL FLOWSHEET

First cycle

The principles of separation of uranium, plutonium and fission-products by solvent extraction processes are well known. The tetra and hexavalent nitrates of plutonium and uranium are much more effectively extracted than the nitrates of lower valency (*1*) (Table 2).

On mixing the conditioned feed solution with the organic solvent and allowing the phases to separate, the heavy metal nitrates are extracted into the solvent whilst the fission product nitrates remain for the most part in the aqueous phase which becomes the highly active waste raffinate.

To obtain increased decontamination, the solvent phase is stripped with an aqueous phase which removes that fraction of the fission products which has accompanied the uranium and plutonium into the organic phase. Similarly the aqueous raffinate is contacted with fresh solvent to extract the last traces of actinides and so reduce losses to waste. A single cycle of operations consists of a number of such extraction and stripping stages (up to a dozen of each) in a continuous counter-current operation. The number of stages, the relative volumes of solvent and aqueous phases and the exact chemical compositions of these are optimized to achieve maximum fission product decontamination, high actinide element recovery and minimal solvent usage. Typical values for a first extraction cycle using 20% TBP in hydrocarbon are given in Fig. 1 (*2*).

In principle, apart from inter-cycle or intra-cycle chemical treatments, the subsequent cycles are analogous to this first cycle. The aim of the development chemist is to meet the process specifications as economically as possible by choosing for each cycle, the most suitable values of the available variables, namely, acidity, salt content, solvent-aqueous ratios in extraction and strip sections, residence time, and temperature.

TABLE 1 *Composition of 1 tonne U fuel after 1000 MWd/ton irradiation, cooled for 100 days (irradiation time 300 days)*

ELEMENT	APPROX. WEIGHT	*ACTIVITY, CURIES
U	988 kg	—
Pu	800 g	—
Cs	110 g	13,100
Sr	40 g	41,500
Ba	40 g	4200
Y	20 g	51,000
La	40 g	—
Ce	100 g	174,000
Pr and other rare earths	155 g	15,000
Zr	115 g	112,000
Nb	5 g	203,000
Mo	85 g	—
Tc	25 g	—
Ru	55 g	37,000
Rh	12 g	—
Other elements	40 g	2000
	TOTAL ACTIVITY	652,800

**The activity from short-lived daughters of Cs-137, Sr-90, Ce-144, Ba-140, and Ru-106 is included with the parents.*

Subsequent cycles

To achieve further decontamination of the uranium-plutonium nitrate mixture, a second fission product decontamination cycle may follow immediately after the actinides have been backwashed from the solvent into aqueous solution. Alternatively, the uranium and plutonium may be separated from one another and further fission product decontamination carried out on the separate streams. The choice is not simple.

Since the main constituent which determines solvent and aqueous volumes and the size of the plant is the uranium which is taken to near saturation concentrations, separating this from the plutonium at an early stage permits greater flexibility in subsequent processing of the separate streams. Treatment in each case can then be tailored to the one constituent. Thus for a uranium stream without plutonium, conditions can be chosen to give maximum decontamination coupled with minimum size of plant, minimum solvent usage, and minimum volumes of effluent requiring disposal treatment—all at the expense of some loss of the comparatively cheap and innocuous depleted uranium. With the more valuable and noxious plutonium present, this philosophy could not be applied to the same extent. Again on the much smaller scale of the plutonium stream, more costly treatments can be applied than would be acceptable on the large scale of the uranium stream.

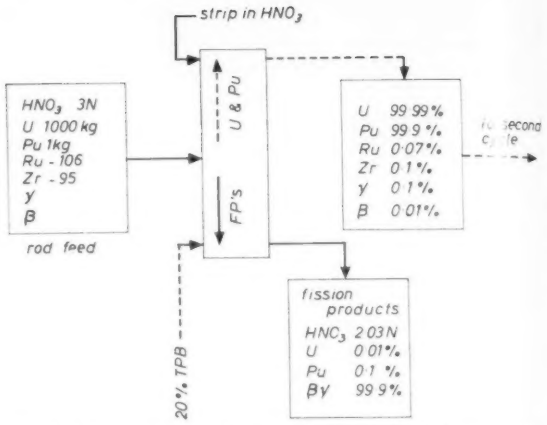
The alternative method of keeping together the two actinides for further joint decontamination has, however, definite advantages. Thus decontamination of the plutonium from fission products is often improved when the solution is saturated with uranium. Adverse effects on the plutonium of solvent degradation products (*vide infra*) are reduced in the presence of uranium. Another important advantage is that the second cycle raffinate, still containing considerable fission product activity, is again salt-free and so can be evaporated to small bulk for permanent storage. The corresponding raffinate when early uranium-plutonium separation has been employed cannot be so concentrated since the normal method of separation of the actinides uses a reducing salt which finally arrives in the effluent.

On balance, the advantages lie marginally in favour of the latter (late-separation) scheme. The uranium and plutonium are removed from the solvent by means of a compound acid back-wash which efficiently extracts them into the aqueous phase. A further measure of decontamination from fission products is achieved at this stage. The solution of uranium-plutonium nitrates is reconditioned with further nitric acid and passed forward to a second solvent extraction cycle in which further decontamination occurs. The uranium and plutonium are then separated.

TABLE 2 *Distribution coefficients between organic and aqueous phases for U, Pu, and F.P. nitrates at 20–25°C* (1)*

METAL OR RADICAL	MOLARITY	DISTRIBUTION COEFFICIENTS (O/A) For I	II
UO_2(II)	10^{-2}–10^{-3}	5	30
PuO_2(II)	10^{-2}–10^{-3}	0·7	3
Pu(IV)	10^{-2}–10^{-3}	1·3	20
Zr(IV)	tracer	0·01	1
Ce(IV)	tracer	0·01	0·2
(RuNO) as trinitrate	10^{-2}–10^{-3}	10	0·01
Pu(III)	10^{-2}–10^{-3}	0·015	0·01
Ce(III)	tracer	0·04	0·02
Y(III)	tracer	0·01	0·02
Nb	tracer	0·01	0·01

**Stirring times from ½ to 5 minutes. Organic phase 20% tributyl phosphate (with hydrocarbon diluent and in equilibrium with respect to water and nitric acid with aqueous phase). Aqueous phase at equilibrium: I, 1M HNO_3; II, 6M HNO_3*
For Ce(III), data are for 50% TBP.



Typical first cycle of solvent extraction using 20% TBP/OK (Fig. 1)

Separation of uranium and plutonium

The mixed uranium-plutonium nitrates come from this second cycle in the solvent stream. Reference to Table 2 indicates that if the plutonium is reduced to the trivalent state, it can be back-washed from the solvent by an aqueous stream, leaving the uranium behind in the solvent. The commonly used reductant for plutonium is ferrous sulphamate added in the aqueous back-wash solution. The sulphamate anion serves to stabilize the ferrous ion against traces of nitrous acid in the nitric acid solution. As before, the aqueous plutonium bearing phase and the uranium laden solvent are washed with solvent and aqueous solutions respectively in a number of extraction and stripping stages. The uranium is subsequently back-washed from the solvent stream by very dilute nitric acid.

Uranium purification and recovery

The main uranium stream, now substantially free of plutonium and fission products, undergoes a further purification cycle to remove the last traces of these. Immediately before this an intercycle treatment is given. In this the aqueous liquor is held at an elevated temperature for several hours or may be evaporated to smaller bulk as in some US processes. Such treatment is designed to effect changes in the fission product species, especially of ruthenium, which will permit further decontamination by solvent extraction. This is logical since the fission product species remaining after the earlier decontamination cycles are those of maximum extractability into solvent and must, if possible, be converted into the less extractable forms.

After the inter-cycle treatment the uranium solution passes through a solvent-extraction cycle for final fission product decontamination. Traces of plutonium are efficiently removed at this stage by a ferrous sulphamate strip. The uranium, now in solvent, is finally obtained as pure uranyl nitrate solution on back-washing with very dilute acid. After evaporation, the uranyl nitrate is continuously denitrated at elevated temperature to yield the trioxide for shipment to the fuel manufacturing plant.

Plutonium purification

The trivalent plutonium in aqueous solution containing excess of ferrous sulphamate is re-oxidized with sodium nitrite to the tetravalent (solvent-extractable) form, and then extracted into solvent. Since the aqueous feed has a high plutonium concentration, α radiolysis of the entrained TBP occurs on standing. The consequent breakdown products e.g. dibutyl phosphate form complexes with plutonium which are difficult to wash out of solvent in subsequent stages and so increase plutonium losses. For this reason no hold-up of the feed solution to the purification cycle (e.g. for accountancy purposes) must occur before the oxidation and solvent extraction. The plutonium is back-washed from the solvent by dilute nitric acid without the help of ferrous sulphamate which would permit a much smaller back-wash volume. This is to avoid:

(*a*) contamination by cations of the pure plutonyl nitrate

(*b*) the limitations on evaporation which the addition of such cations would impose.

After a further purification cycle if required, the aqueous solution of pure plutonium nitrate is evaporated to small bulk, the plutonium continuously precipitated as oxalate, and thence converted to oxide. The latter may be used as such in the fabrication of new fuel elements of an advanced type or may be converted to the tetrafluoride to be finally reduced by calcium to the metal.

SOLVENT DEGRADATION AND RECOVERY

As indicated in the previous section, TBP can undergo radiolysis or acid hydrolysis with the formation of degradation products, particularly dibutyl phosphate (DBP) and monobutyl phosphate (MBP). The radiolysis may be due to the intense $\beta\gamma$ radiation from fission products in the feed solution or to α radiation in the concentrated plutonium streams. The DBP and/or MBP form very stable complexes with plutonium, uranium and certain fission products. The overall effect of this is to increase the losses of plutonium and uranium and to decrease the decontamination from the fission products. For these reasons hydrolysis of TBP is avoided as far as possible and in particular, the build-up of these complexes in the recycled solvent is prevented. To do this the solvent is washed before re-use with alkalis e.g. sodium carbonate and sodium hydroxide which effectively remove the acid hydrolysis products and strip out the solvent contaminants to form a radioactive aqueous waste of high salt content. Experience shows that there are distinct advantages in retaining the solvent used in the first highly active section in a closed cycle since:

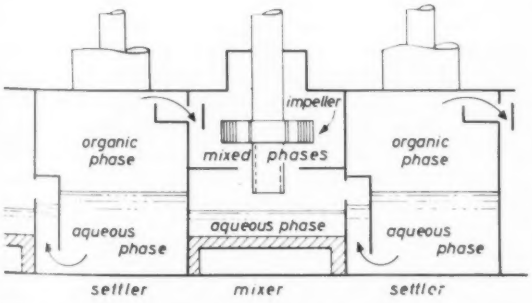


Diagram of the horizontal mixer-settler contactors (Fig. 2)

(*a*) it is of smaller volume than that used in the medium active sections of the plant and

(*b*) it is exposed to the greater $\beta\gamma$ flux and so undergoes significant hydrolysis.

Solvent treatment is effective for a time but after several months renewal is advisable. For the medium-active solvent kept in its own cycle the period before renewal may well be several years if the inter-cycle treatment with alkalis is regularly applied.

Acid hydrolysis becomes more significant when aqueous solutions containing entrained TBP are evaporated, and leads to inefficiency in subsequent solvent extraction processes. Inter-cycle evaporation is avoided therefore if possible, particularly on plutonium streams in which, in the absence of uranium, the complexing action on plutonium is greater.

TREATMENT OF WASTE LIQUORS

The use of TBP/OK as the solvent permits the design of a salt-free process which gives rise to effluent liquors that can be evaporated by large factors. The concentrates can then be sent to permanent storage in underground, concrete-shielded, stainless steel tanks. The high cost of such storage (up to £1/gal) limits its use to the small volume of concentrates from the evaporation processes. The condensates are to be fractionally distilled to recover the nitric acid for re-use.

The problem of the disposal of activity is greatly simplified by acceptance of this principle of evaporation, so far as possible, of all active effluents and subsequent storage of the concentrates so obtained. Such treatment can be employed for all the main line effluents of high and medium activity, leaving only the salt-bearing liquors from the plutonium purification and solvent recovery processes containing iron and sodium salts respectively to be treated differently. In the latter case the liquors are stored for the optimum number of years to attain minimum activity since the fission products, especially Ru-106 (half-life 1 year) decay at the same time as the α-active americium 241 builds up as a result of the β decay of Pu-241 (half-life 12·9 years). After storage the liquors are acidified and conditioned to give high nitrate ion content and are then passed through an anion exchange column which retains the last traces of the long-lived α-active plutonium. The raffinate, containing the ruthenium and americium is sent, after monitoring, to sea disposal. The plutonium is eluted from the column periodically and returned to the main process. The iron-bearing effluent is treated after a decay period in a similar manner. Efforts have been made to substitute a non-ionic reductant of equal efficiency for the ferrous sulphamate in order to obtain a salt free raffinate suitable for evaporation and storage. These have not been successful to date.

Active non-process effluents such as wash-out and decontamination liquors are treated in the same way, namely evaporation of those liquors of low salt content and storage of the concentrates, and storage followed by ion exchange of other liquors. In the latter case some form of precipitation and floc treatment may precede the ion-exchange process.

By such means the amount of activity finally disposed to sea is reduced to a small fraction of that from the present butex process in which a number of the active raffinates are salt-laden and cannot be evaporated. The flexibility of the site and site operation are thus safeguarded.

CRITICALITY CONSIDERATIONS

The large quantity of plutonium arising from the civil power programme imposes problems in the processing plants on the grounds of criticality. These problems do not normally arise whilst the plutonium is associated with the uranium as the latter would cause super-saturation of the solutions long before they would become critical. They arise more particularly in the plutonium purification and finishing processes. The advantage of continuous processing is that equipment can be designed with the necessary large through-put but of low hold-up so as to avoid undue build-up of fissionable material. In addition, wherever possible, equipment of eversafe geometry is specified. By this is meant that the dimensions of the equipment are such that whatever concentration of plutonium is in the liquors, a critical excursion cannot arise (because of neutron losses). Where geometrically eversafe equipment is not possible, control by concentration limitation is imposed and checked by frequent instrumental and analytical assay.

PLANT AND EQUIPMENT

The experience gained as a result of eight years operation of the butex plant and process has been invaluable in the chemical engineering design of the new plant. In the design of the former, the guiding philosophy was to eschew mechanical equipment with moving parts in the active portions of the plant and to design for the movement of liquids by gravity flow, vacuum lift etc., in static equipment. It, therefore, gained in simplicity of design and greater intrinsic reliability at the cost of proliferating the number of head and storage vessels occasioned by a vacuum transfer system. Static packed columns of lengths from 45 to 90 ft were chosen for the main contactors in the highly and medium active sections. The operation of these on a gravity flow system made necessary a very costly and heavy concrete biological shield housed within a building 200 ft high.

For the new separation plant a more conventional chemical engineering approach has been made with consequent economy. In this approach the radioactivity is considered, not as a completely over-riding factor, but as an additional though important parameter which must be taken into account.

The departure from solid forged dissolver vessels to a new design of welded construction has removed the limitation on dissolver size and permits a smaller number to be employed. Much work has been carried out on the development of pumps, contactors, evaporators and valves etc., to establish the most suitable type of conventional equipment for use with radioactive liquors and then to improve the reliability of the design chosen to ensure confidence in use.

Instrumentation of the new plant is to be carried much further than in the butex plant in which it was largely used for the provision of information—confirmed by later chemical analysis—on which manual or semi-manual control could be based. In the new plant, duplication between instrumental and chemical analysis will be much reduced and, without attempting the difficult design of a fully automatic plant, the use of instruments for control as distinct from record purposes will be carried out wherever possible, consistent with safety and efficiency.

The solvent extraction equipment is based on the use of horizontal mixer-settler contactors throughout the process. In these the two phases are mixed together repeatedly in a series of stirred vessels, followed by settling chambers in which phase separation takes place. Many variants of this type of extractor have been designed but the essential features are illustrated in Fig. 2. Their use in the new Windscale process has a number of advantages over the use of packed columns of direct economic importance. Thus the capital outlay associated with the equipment is less and the improved (horizontal) layout which is possible permits greatly reduced building and shielding costs. Because of this it is permissible to err on the generous side in respect of the number of extraction, back-wash and strip stages allocated to any cycle thereby achieving a greater margin of safety in efficient operation and a greater flexibility of plant for exploitation in the processing of non-standard feeds.

The flexibility of the mixer-settler unit is shown in its ability to operate with a minimum density difference over a wide range of flow rates and solvent-aqueous ratios. Carry-over of interfacial crud or solid material into the solvent phase has been shown to be negligible because the multiple solvent/aqueous interfaces in the settlers of the strip sections act as efficient filters for particulate matter. The solids are found to build up at the interface and fall to the aqueous phase where they are swept out of the box. Some build-up occurs below the lower (aqueous) transfer port but the level does not rise above this and causes no problem. The accumulated solids can be sucked off at infrequent intervals (say of 1–2 years) and provision for this to be carried out remotely (using steam ejectors) has been made in the highly active section where direct access is difficult.

Confidence has been obtained during the development programme in the operational reliability, freedom from blockages, ease of crud removal etc., of the mixer-settlers and remaining work seeks to optimize the operating characteristics, namely, shape, size and speed of stirrer, size of mixers and of settlers, size and position of transfer ports and the like.

An important operational advantage of mixer-settlers over columns is the ability to close down the process temporarily when required without draining the contactors and to restart without delay. Generally operational costs are expected to be somewhat less than with packed columns. These savings are additional to those derived from the chemistry of the process e.g. in reduced materials usages and losses.

An important development relates to the finishing end of the process in which solid compounds of plutonium are handled. In the butex plant the precipitation of plutonium oxalate and subsequent steps are carried out batchwise and so necessitate strict control of batch size on criticality grounds. Recent work has led to the successful development of continuous methods for the stages up to the provision of the plutonium fluoride and so eased the control problem arising from the much greater quantities of plutonium to be handled in future years. The further step of continuous fluoride reduction to metal is more difficult and leads to only marginal savings.

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The economic and thermodynamic advantages of seven different steam cycles for organic moderated marine reactors are reviewed here

Steam conditions for marine organic moderated reactors

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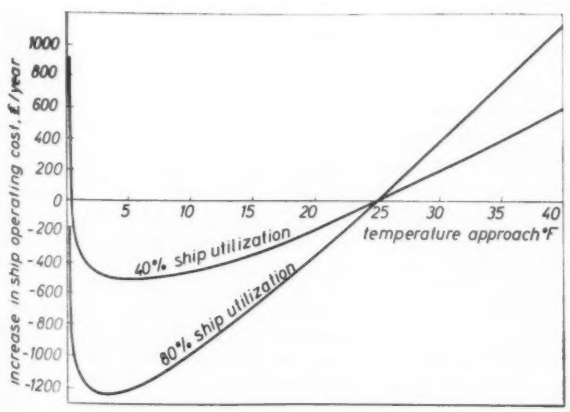
THE PRESENT designs of organic moderated and cooled reactors allow reactor coolant outlet temperatures of 330–345°C (626–653°F) to be achieved with core temperature rises of 35–50°C. Thus steam temperatures of the order of 600–640°F are possible, the exact figure depending on the temperature approach between the reactor coolant and the final steam temperature which is allowable on economic and other grounds. A balance is struck between more heat exchanger surface and its additional cost and bulk and the beneficial effect of a higher steam temperature on the overall cycle efficiency and operating costs. Some results of a heat exchanger study for a 20,000 S.H.P. ship are given in Fig. 1. The economic optimum can be seen to correspond to a temperature approach of about 5°F. Reductions in temperature approach require additional surface area in the superheaters and this in turn has repercussions on plant safety and reactor plant containment size and design pressure. It is difficult, and perhaps undesirable, to place a monetary value on some of these considerations and thus Fig. 1 can only serve as a guide. For our present marine OMR designs a temperature approach between 15 and 25°F is considered to give a compact heat exchanger arrangement without sacrificing a great deal in the way of fuel economy.

CHOICE OF STEAM CYCLE

Table 1 gives overall efficiencies and reactor output for the various steam cycles considered below using comparable steam conditions. In each case the condenser vacuum is assumed to be 28·5 in. Hg and the final feed temperature to be 320°F (300°F for the straight expansion cycle).



How the superheater temperature approach affects the operating cost of a 20,000 S.H.P. dry cargo ship (Fig. 1)

Straight expansion steam cycle

With or without water extraction

The use of high pressure in a straight expansion cycle is limited by the adverse effects of excessive moisture on the L.P. blades and casing. Present practice is to limit the theoretical moisture content of the steam exhausted to the condenser to 13–15%. This has been specified for turbines with blade tip speeds up to 1250 ft/s, and in some cases protective blade shields of Stellite or similar material are provided.

POSSIBLE STEAM CYCLES

1. Straight expansion steam cycle
2. Straight expansion steam cycle with water extraction between turbine cylinders
3. Two zone reactor core with straight expansion steam cycle
4. Straight expansion steam cycle with a separately fired steam superheater
5. Reheat steam cycle, reheating by live steam between turbine cylinders
6. Reheat steam cycle, reheating by a separately fired reheater between turbine cylinders
7. Reheat steam cycle, reheating by the reactor primary coolant between turbine cylinders

The degree of erosion of the L.P. turbine blades is mainly dependent on the blade material, the peripheral blade speed, the moisture content and the oxygen and carbon dioxide concentration in the steam. For a given turbine design therefore there is a limiting exhaust wetness and a maximum allowable steam pressure for any value of steam temperature at the turbine manoeuvring valves. With a

TABLE 1 *Comparison of steam cycles (Aux. loads as for a refrigerated dry cargo vessel)*

	1	2	3	3 & 2	4	5	4 & 6	7
CYCLE	STRAIGHT EXPANSION	WATER EXTRACTION	TWO-ZONE CORE	TWO-ZONE CORE AND WATER EXTRACTION	SEPARATELY FIRED SUPERHEATER	REHEAT: LIVE STEAM	REHEAT AND SUPER-HEAT SEPARATELY FIRED	REHEAT: PRIMARY COOLANT
Selected turbine N.C.V. pressure, lb/in²a	265	615	515	815	615	615	615	615
Selected turbine N.C.V. temperature, °F	610	610	700	700	850	610	850	610
Reheat temperature, °F	—	1% wet at L.P. Inlet	—	1% wet at L.P. Inlet	—	570	850	700
Condenser vacuum, in. Hg	28·5	28·5	28·5	28·5	28·5	28·5	28·5	28·5
Final feed temperature, °F	300	320	320	320	320	320	320	320
Shaft horse power	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Reactor heat output, MW	64·1	59·6	58·5	56·7	43·6	60·6	37·6	59·6
Total heat supplied to cycle, MW	64·1	59·6	58·5	56·7	56·5	60·6	54·5	59·6
Overall cycle efficiency, %	23·3	25·0	25·5	26·3	26·4	24·6	27·4	25·0

straight expansion steam cycle, without water extraction (except for the customary interstage drainage belts), relatively low steam conditions are possible; e.g. 280 lb/in²g/600°F at the turbine nozzle control valves (N.C.V.). The addition of an external steam separator between H.P. and L.P. turbine cylinders allows a much higher steam pressure to be used at the turbine manoeuvring valves; e.g. for a N.C.V. steam temperature of 600°F the steam pressure at the N.C.V. can be as high as 1100 lb/in²g with one external stage of water extraction. The use of higher steam pressures may be expected to confer an improvement in overall cycle efficiency principally because of the increase in the available adiabatic heat drop and Rankine efficiency. Figure 2 shows the change in overall cycle efficiency caused by various steam pressures at the manoeuvring valves of a 20,000 S.H.P. OMR ship. The results given in Fig. 2 are based on assumptions which are considered to be realistic and in general follow the methods of steam cycle analysis described by Tyrrell (*1*) and Bonny (*2*). The optimum pressure is seen to be 1000–1100 lb/in², which is high in relation to present merchant ship practice. Vessels of the size quoted above commonly use steam at 600–850 lb/in²g and at 800–950°F.

Although demonstrating that a considerable gain in cycle efficiency results from an increase in steam pressure, Fig. 2 does not establish a corresponding economic gain. To determine the economic value of the use of higher steam pressures a detailed comparison was made of the ship operating cost for a 20,000 S.H.P. OMR tanker for the following cases,

(*a*) Straight expansion steam cycle, with N.C.V. steam conditions 250 lb/in²g/610°F.

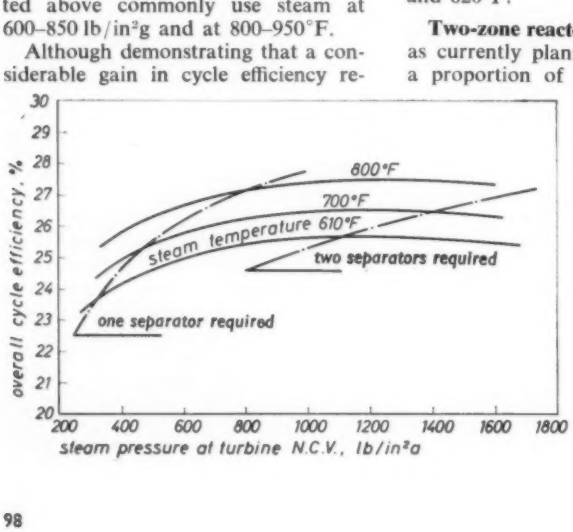
(*b*) Straight expansion steam cycle. N.C.V. steam conditions of 600 lb/in²g/610°F and with a fixed blade, cyclone steam separator between H.P. and L.P. cylinders.

It was found that the ship operating costs per annum for case (*b*) were 1·1% lower than for case (*a*); this figure assumes 80% ship utilization. This reduction in ship costs involves a negligible complication of the ship's machinery and requires only the addition of the steam separator (which is extremely simple and robust, and unlikely to give trouble in service) and an extra condensate pump. Full particulars of an OMR as installed in a refrigerated dry cargo vessel of 13,300 tons deadweight are given by Hawthorne and Cortlett (*3*). The water extraction cycle is used for this proposal and steam is generated at 630 lb/in²g and 620°F.

Two-zone reactor core This system as currently planned involves passing a proportion of the organic coolant flow (5–10%) through the core three times. The remainder of the reactor flow (90–95%) passes through the core once and suffers the normal temperature rise. The bulk outlet temperature of the secondary zone can be 380–420°C, which allows steam temperatures of 690–770°F at the turbine. The variation of overall steam cycle efficiency with steam pressure, for given N.C.V. steam temperatures of 700°F and 800°F is given in Fig. 2. Steam at 500 lb/in²g/700°F could be used in a straight expansion cycle, but a pressure nearer the optimum could be achieved if a steam separator was used. This system is promising and can offer considerable improvements in cycle efficiency and ship operating costs.

The disadvantages of this system involve mainly the reactor and primary coolant circuits. The margin over bulk boiling in the core is reduced (unless the core pressure is increased), extra piping and openings in the pressure vessel are required, and the core structure is rather more complicated. System control is not greatly affected, although various safety margins may be reduced, calling for closer control of reactor transients. Present estimates indicate that the costs of the increase in reactor coolant polymerization rate due to this scheme are not prohibitive and do not invalidate the economic worth of the proposal.

Separately fired steam superheater This system is thermodynamically sound. Heat from the reactor is used to evaporate the feed water, while combustion heat is employed only for the high temperature end of the cycle where it can be used at a high thermal efficiency. However the propulsion plant is more complex and system control is complicated. All the problems peculiar to an oil fired ship, e.g. oil fuel storage and handling, air trunking etc. would be present, together with those to be expected from a mobile nuclear reactor. However as shown in Table 1 at 850°F or higher, overall thermal efficiencies of 26–28%



This shows the way the overall cycle efficiency changes for different steam pressures at the manoeuvring valve of a 20,000 S.H.P. OMR ship, the auxiliary loads are as for a refrigerated dry cargo vessel; the condenser vacuum is 28·5 in. Hg (Fig. 2)

are possible. In addition the superheater normally located inside the reactor containment is not required, thus reducing the containment volume and simplifying the primary coolant circuits. Preliminary economic studies of this steam cycle have established a reduction in ship operating costs relative to the costs for the basic straight expansion cycle of up to 3%, depending on the application and the steam conditions chosen. From an operational viewpoint this system would not be attractive for the first generation of nuclear powered ships. However once the dependability of a nuclear plant is proven at sea then this system may appeal to shipowners because of its economic advantages.

Reheat steam cycle

Live steam between cylinders This method is simple and involves no complication of the reactor primary coolant circuit. However its efficiency is slightly less than the water extraction cycle (see Table 1) and also may be considered rather less dependable than that cycle. The turbine pipework and control valve arrangement is more complicated, and weight and space are adversely affected. Reheating by live steam requires careful optimization of the temperature approach in the reheater, reheating pressure and pressure drop in the reheater and piping. There is reported (*4*) to be at least one ship afloat in which live steam reheating had caused a loss in efficiency.

Separately fired reheater As shown in Table 1, the efficiency of this cycle is comparable with that of the water extraction cycle using the same initial steam conditions (c.f. cycles 2 and 7), but with greatly added cost and complexity. If a separately fired steam heater is to be used it would be preferable to use it first as in scheme 4, i.e. to superheat saturated steam from the primary heat exchangers to the maximum acceptable temperature. The reheat cycle for optimum efficiency ideally requires high boiler steam conditions, at least 650 lb/in²g and 850°F. Such steam conditions are only possible using this scheme in conjunction with scheme 4 or possibly scheme 3, see Table 1.

The reheat cycle has been slow to find favour with ship owners largely because of the increased complexity, weight and cost, and the anticipated reduction in reliability. Some authorities believe the latter objection to be over-estimated; the chief engineer of a large reheat ship (30,000 S.H.P. 680 lb/in²g/850°F/850°F) has stated that operation of the reheat machinery has presented no more difficulties than those normally encountered in a straight cycle installation of the same steam conditions. For the reheat ship quoted above the extra capital cost was stated (*4*) to be £45,000 and the saving on the annual fuel bill was £9000/year. With capital charges at the relatively low figure of 11½% the extra cost is recovered in twelve years.

A. D. Somes (*5*) has stated that 'The reheat cycle had been carefully examined for application to marine power plants. In no case so far had it been possible to demonstrate any economic advantage with reheat aboard ship. This was supported by studies for land installations. For ratings of 50,000 kW and below, it had not been possible to demonstrate any economical advantages for the reheat cycle, except in those areas where fuel costs were very high'. This statement was based on studies made by a US company and is therefore influenced by their manufacturing conditions and fuel costs. The economic value of reheat in a British ship of above say 25,000 S.H.P. remains a matter of some doubt, due partly to the lack of exact comparative data.

Using primary coolant Many of the disadvantages of the previous reheat cycles apply also to the method of reheating by the primary coolant between turbine cylinders, i.e. it is more complicated and heavy and costly than the water extraction cycle or the straight expansion cycle. Large bore steam pipes have to be carried back to the reheater, which for reasons of safety must be located inside the containment vessel. The pipe runs are therefore long and the pressure drops correspondingly larger, thus reducing the thermodynamic gain. The reheaters would be larger than the primary superheaters and together with the associated pipework would probably require an increase in the size of the containment vessel. The reheater would be another heat exchanger to incorporate in the primary coolant circuit, increasing the reactor pumping power and adversely affecting (to an unknown degree) the reliability and safety of the reactor plant. As can be seen from Table 1, for the same steam conditions, reheat cycle (*7*) is equalled in efficiency by the water extraction cycle.

COMPARISON OF CYCLES

Table 1 gives steam cycle efficiencies for all of the steam cycles previously discussed; common steam conditions of 600 lb/in²g and 610°F at the manoeuvring valves have been used where applicable. On grounds of efficiency alone the separately fired superheat and reheat cycles are the best, closely followed by the two-zone core and water extraction cycles. Increases in the reactor coolant outlet temperature will narrow the gap between these cycles, which is due to the higher steam temperatures possible using nuclear and fossil fuels in combination.

The preferred steam cycle for an early OMR ship is the water extraction cycle (*2*). An assessment of the various cycles shows that, apart from the conventional straight expansion cycle (*1*), the water extraction cycle is the simplest, lightest and cheapest and is only bettered in efficiency to any degree by the separately fired superheater and reheater cycles and the cycle using a two-zone reactor core. In addition cycle (*2*), relative to the straight expansion cycle, is shown to confer a worthwhile reduction in ship operating cost (approx. 1·1%).

A two-zone core (with or without water extraction) produces a further gain in efficiency and would be attractive providing that the increased complication in the reactor design was acceptable. This cycle may be considered practical for the second generation of nuclear ships.

CHOICE OF STEAM PRESSURE

The following remarks refer only to the water extraction cycle.

Figure 2 shows that the best cycle efficiency is obtained at a boiler pressure of 1100 lb/in². This pressure is high by present-day standards and would not be favoured for an early nuclear ship. Boiler pressures of 600–750 lb/in²g are considered to be good modern practice. Estimates of operating cost made for a 20,000 S.H.P. ship show that the economic optimum steam pressure lies between 600 and 800 lb/in²g depending on the type of ship. Ships with a high usage factor such as tankers would favour the higher pressure.

The heat transfer surface area provided in the main heat exchangers increases rapidly with rises in steam pressure above 600–700 lb/in² and causes increases in reactor containment size and design pressure. These changes adversely affect reactor and ship safety and inevitably influence the choice of steam pressure, which will however lie within the range quoted above, i.e. 600–800 lb/in²g.

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THE DIRECT GENERATION OF ELECTRICITY—1

by B. C. LINDLEY, B.Sc.(Eng.)
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NO MOVING PARTS IN THESE ELECTRICITY GENERATORS

- Thermoelectric, using semiconductor materials
- Thermionic, based on the emission of electrons from a heated surface
- Magneto-hydrodynamic, based on the interaction of an electrically conducting fluid with a magnetic field
- Electrochemical fuel cell in which the process of electrolysis is reversed

In the first three methods, heat has to be first produced and is then converted into electrical energy; in the fuel cell, chemical energy is converted directly into electrical energy.

The first two of these methods are discussed this month in Part 1 of the article.

DIRECT GENERATION of electricity may soon become an important part of the overall pattern of power generation. Steam turbo-alternator plant, at present almost universally employed for large-scale generation of electrical power, is capable of development with respect to improvements in steam conditions, cycle refinements, and advances in alternator design. These lead to small but worthwhile increases in overall thermal efficiency. The improvements, however, are usually accompanied by an increase in capital costs due to the materials and to the constructional methods needed for operation at higher temperatures and pressures and the increasing complexity associated with cycle refinements. These increases are largely offset by having larger power plants, but it is increasingly difficult, mainly on account of siting requirements, to incorporate very large power blocks into the national grid.

Future of steam plant

The ultimate development of steam plant may, in the UK, be exemplified by 1000 MWe paired units operating on an air-steam binary cycle. In other countries larger or smaller sets may be more suitable. Depending upon the initial temperature and a more accurate knowledge of the properties of steam in the supercritical region, a maximum thermal efficiency is achieved at an initial pressure between 5000 and 10,000 lb/in²g. Coal or oil-burning plant with steam conditions of up to 10,000 lb/in² and 1400°F, with two or more reheat stages, should be coming into service in about fifteen or twenty years' time and will achieve overall station thermal efficiencies of 45%. High temperature nuclear reactor plant with similar conditions should follow later.

Power sources used at present

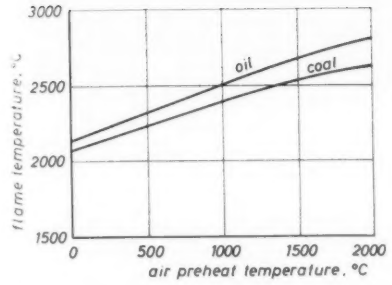
In present technology, energy is produced by the combustion of fossil fuels or by the fission of radioactive species. It is likely that these will be the main power sources for the next few decades, although advances may eventually occur in the economic production of chemical and free radical fuels and in thermonuclear fusion reactors. Power from the sun, wind and tide can probably be discounted, except in special instances; hydroelectric power will be exploited as far as it is economic.

If the available energy is initially converted to thermal energy the efficiency of subsequent conversion to electrical energy in a practical heat engine cycle can not exceed the Carnot cycle efficiency.* The value of this parameter for present steam cycles is about 0·65; a value slightly greater than 0·7 will ultimately be achieved. The corresponding overall station thermal efficiencies are about 0·4 and 0·45.

Higher temperatures

The highest attainable flame temperatures with fossil fuels are about 2000°C; this can be increased a few hundred degrees by preheating the combustion air, as shown in Fig. 1 for typical coal and oil fuels. The gain is limited by the energy of chemical dissociation. The gas temperature achievable in a gas-cooled fission reactor is limited by the melting points of materials and by heat transfer. High temperatures can be expected in thermal breeder reactors developed from the OEEC Dragon Project; the

*The efficiency, η, of a reversible (Carnot cycle) heat engine, working between a heat source at absolute temperature T_1 and a heat sink at absolute temperature T_0 is $\eta = (T_1 - T_0)/T_1$.



Highest flame temperature of combustion with air of coal and oil as a function of air preheat temperature (Fig. 1)

cores will contain only ceramic fissile, fertile and moderator materials. Graphite, which sublimes at 3650°C at atmospheric pressure, is the most likely choice of moderator. No known nuclear fuel will remain in the solid state at such a high temperature but gas temperatures between 2000 and 2500°C should nevertheless be attainable. Even higher temperatures could in principle be achieved with a liquid- or gas-phase fuel contained in graphite. High temperatures may also be obtained in advanced forms of fast reactor. In a nuclear solid-state direct generation system the maximum temperature in the reactor (fuel centre temperature) could be utilized.

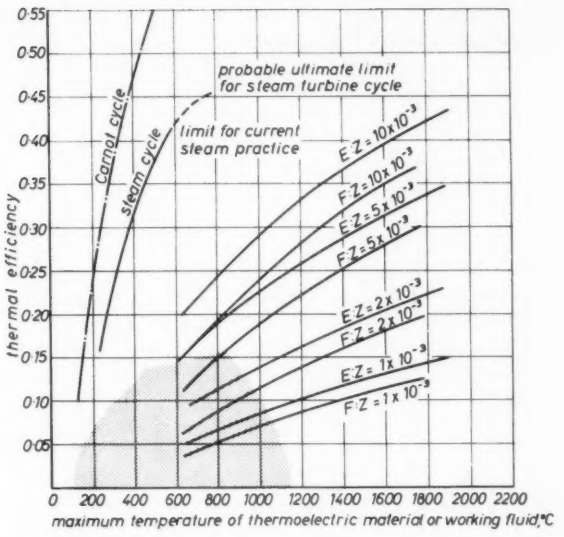
If temperatures in the range 2000 to 3000°C can be accepted in any form of energy conversion equipment the Carnot cycle efficiency is increased to between 0·75 and 0·9, with an appreciable potential increase in overall thermal efficiency. If the chemical energy of fuels is converted directly to electrical energy in an electrochemical process the Carnot limit does not apply and thermal efficiencies approaching 100% are potentially available.

IT HAS BEEN DONE

Nuclear heat can be directly converted into electricity using thermionic and thermoelectric devices. A thermionic test cell has been used successfully in a Los Alamos research reactor to produce closed circuit currents as high as 35 A and an open circuit voltage of 3·8 V. The cathode was a solid solution of ZrC-UC, and the anode stainless steel. A thermoelectric fuel element has been proposed by Westinghouse using a stainless steel-clad UO_2 element which is surrounded by a layer of mixed valence thermoelectric materials which generate voltage in series. In general, the thermoelectric schemes are simpler and more robust but thermionic converters are capable of a higher converter efficiency.

Economic advantages of direct conversion

High thermal efficiency can be justified for two reasons: if not accompanied by a compensating increase in capital cost the net cost of producing electrical power is reduced; an accompanying increase in capital cost may result in no reduction of power cost but the available energy supplies are conserved. At the present time, four techniques



Shaded area shows range for present thermoelectric materials (isothermal heating)
Z figure of merit of thermoelectric material
E Fossil-fuel (recuperative cycle) F fossil-fuel

Thermal efficiency of steam cycle and thermoelectric generating systems (open-cycle fossil-fuel plant) (Fig. 2)

for the direct generation of electricity are being considered. Each of these offers some prospect of reducing the complexity and increasing the overall efficiency of generating plant; the effect will be to reduce the capital, fuel and operating costs and thus the net cost of power.

THERMOELECTRIC GENERATION

The thermoelectric generator consists of an assembly of solid-state semiconductor thermocouples, the 'hot' junctions being maintained at a temperature T_1 and the 'cold' junctions at a temperature T_0. The efficiency is (*1*)

$$\eta = \frac{T_1 - T_0}{T_1} \cdot \frac{\dfrac{m}{m+1}}{1 + \dfrac{m+1}{ZT_1} - \dfrac{T_1 - T_0}{2T_1} \cdot \dfrac{1}{m+1}}$$

The figure of merit, Z, contains only electrical and thermal properties of the semiconductor materials; for a generator thermocouple consisting of blocks of p-type and n-type semiconductor with optimum dimensions the figure of merit is given by

$$Z = \frac{\alpha^2}{\left[\left(\dfrac{k_p}{\sigma_p}\right)^{\frac{1}{2}} + \left(\dfrac{k_n}{\sigma_n}\right)^{\frac{1}{2}}\right]^2}$$

where α is the Seebeck coefficient of the combination. For maximum power transfer into the load, $R = r$ and $m = 1$, giving

$$\eta = \frac{T_1 - T_0}{T_1} \cdot \frac{1}{2 + \dfrac{4}{ZT_1} - \dfrac{T_1 - T_0}{2T_1}}$$

For maximum efficiency, however

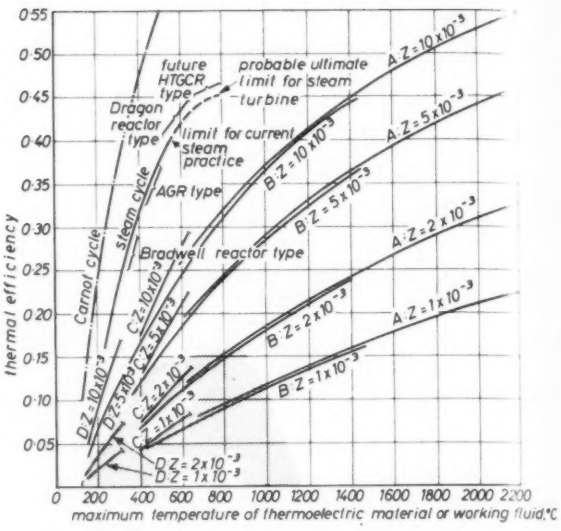
$$\eta = \frac{T_1 - T_0}{T_1} \cdot \frac{M - 1}{M + \frac{T_0}{T_1}}$$

where $M = \left(\frac{R}{r}\right)_{opt} = \left[1 + \frac{Z}{2}(T_1 + T_0)\right]^{\frac{1}{2}}$

The first factor, $(T_1 - T_0)/T_1$, in the expressions for efficiency, is the Carnot limit, while the second term represents the reduction in this due to Joule heating and heat losses by conduction. The nearness of approach to the Carnot cycle is a function of material properties, and research is directed towards substances with high figures of merit and which can operate at extremely high temperatures.

The open-circuit voltage of a single thermocouple is $V_0 = \alpha(T_1 - T_0)$; α is generally in the range 100–300 μV/°C and a large number of elements must be connected in series to give a useful output voltage. The output is d.c. although with advances in semiconductor techniques a pulsed output might be obtained. In a previous assessment (2) the work on thermoelectric materials was reviewed and performance parameters for thermoelectric generators were derived. The optimization of a practical design is discussed in detail by Sherman *et al.* (3).

The transfer of thermal energy to a generator by a circulating fluid leads to low efficiency and raises the capital cost; to achieve maximum efficiency and utilization of the thermolectric material the heat source (and heat sink) should be as nearly isothermal as is practical. With fossil-fuel heat sources either a large proportion of the heat in the combustion gases is rejected, or much of the thermoelectric material is heated by gases at a low temperature. The system can be improved, with an increase in capital cost, by heat exchange between the exhaust gas and incoming air. A nuclear heat source can be designed to transfer energy more nearly isothermally. If the thermoelectric material in an external generator is heated by the reactor coolant a high generator outlet temperature is not a major disadvantage since, being a closed cycle system, heat rejected at a high temperature is merely passed back to the reactor and not wasted.



Shaded area shows range for present thermoelectric materials (isothermal heating)

Z figure of merit of thermoelectric material
A water cooled and moderated reactor with thermoelectric fuel elements
B gas cooled reactor with external thermoelectric generator
C sodium cooled first reactor with external thermoelectric generator
D organic moderated reactor with external thermoelectric generator

Thermal efficiency of steam cycle and thermoelectric generating systems (closed-cycle nuclear plant) (Fig. 3)

A more attractive system is that in which the thermoelectric material is incorporated in the reactor fuel element either as a layer adjacent to the fuel or by the production of a fuel which itself has suitable thermoelectric properties. In the latter case the only limit is the maximum permissible temperature in the nuclear fuel and the conversion efficiency is not reduced by heat exchange losses.

Estimates have been made of the thermal efficiency representative of several possible systems, incorporating limits inherent in the systems, and with arbitrarily selected

SYMBOLS USED

A	constant in Richardson's equation
B	magnetic field strength
G	free energy
H	enthalpy
I	current
J	emission current density
K	Boltzmann constant
M	value of m for maximum efficiency
P_1	absolute pressure before expansion
P_0	absolute pressure after expansion
P_c	power loss in thermionic generator due to conduction of heat along electrical leads
P_e	power loss in thermionic generator due to the resistance of electrical leads
P_r	power loss in thermionic generator due to radiative heat transfer from cathode to anode
R	external load resistance
S	entropy
T	temperature
T_1	absolute temperature at which heat is accepted
T_0	absolute temperature at which heat is rejected
U	velocity
V	output voltage
V_i	ionization potential (energy required to dissociate molecule to ion and electron)
V_0	open circuit voltage
Z	thermoelectric figure of merit
e	electron charge
e_i	ion charge
k	thermal conductivity
m	ratio of external load resistance R to internal resistance r
n_e	electron concentration
n_i	ion concentration
n_n	neutral concentration
r	internal resistance
t	time
y	width of magnetohydrodynamic generator duct
α	Seebeck coefficient
δ	space-charge barrier
ϕ	electrode work function (energy required to remove one electron completely from the material)
η	thermal efficiency
μ_e	electron mobility
μ_i	ion mobility
σ	electrical conductivity

mean values of the thermoelectric figure of merit. Figures 2 and 3 show the results; the efficiencies are expressed as a function of the maximum temperature of the thermoelectric material. Also shown is the range of efficiency corresponding to present materials, as derived from the available data. At 300°C a figure of merit, Z, of about 3×10^{-3}°K has been achieved, whereas at about 1100°C the best material has given $0{\cdot}1 \times 10^{-3}$°K. By staging the materials, so that each achieves its optimum performance over the temperature range at which it operates, the highest possible overall efficiencies can be realized.

Based on the efficiencies of Figures 2 and 3 approximate estimates (*4*) of the cost of power have shown that, for external thermoelectric generators, mean figures of merit between 5 and 10×10^{-3}°K^{-1} are necessary before the cost falls to that from steam plant. It is concluded that the only thermoelectric system worthy of further study is a nuclear reactor with thermoelectric fuel elements. The low thermal conductivity of the refractory fissionable fuels is no longer a disadvantage, and heat can be rejected to water at a low temperature and nominal pressure, thus eliminating the high cost of a pressure vessel. The nuclear power plant is thereby much simplified.

A considerable effort is being devoted in the USA to the development of semiconductor materials for generators. The prediction on a theoretical basis of the thermoelectric figure of merit of a given material is not yet possible, although the effect of many factors is known (*5*). Results to date (*6, 7*) show that the achievable figures of merit are low, and that there may be little prospect of very considerable further improvement.

THERMIONIC GENERATION

In a thermionic diode generator electrons are emitted from a cathode of work function ϕ_1 maintained at a temperature T_1 and collected by an anode of work function ϕ_0 maintained at a temperature T_0. The maximum cathode emission current when a positive potential is applied to the anode is given by Richardson's equation:

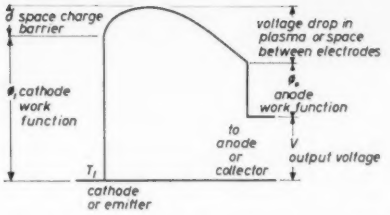
$$J_1 = A\,T_1^2 e - \frac{e\phi_1}{KT_1}$$

A similar expression represents the anode emission current; this can be made negligible by choosing a low enough temperature T_0. In the absence of an accelerating field a current can be drawn through an external circuit connecting the anode and cathode. However, the accumulation of a space-charge barrier δ, as shown in Fig. 4, limits the interelectrode current. A number of techniques are being investigated for overcoming this limitation; these include reducing the interelectrode spacing to less than 0·001 cm (*8*), introducing positive ions (usually caesium vapour) to neutralize the electron cloud forming the space charge (*9, 10*) and the use of auxiliary fields to guide the electrons.

In conditions where the space charge and the anode emission are negligible the thermal efficiency is given by

$$\eta = \frac{J_1 V - P_e}{J_1(\phi_1 + 2KT_1/e) + P_r + P_c}$$

The output voltage of a single diode is typically 1 to 3 V and there is a good prospect of achieving overall efficiencies of up to 0·25 with current densities of 100 A/cm². An efficiency of 0·15 at a current density of 15 A/cm²



Potential diagram of a thermionic generator (Fig. 4)

has been obtained in an experimental diode device (*11*); slightly higher efficiencies and current densities up to 60 A/cm² have been reported (*12*). The use of auxiliary grid control to give a pulsed output would facilitate transformation to high voltage a.c. for transmission.

The requirements for heating the cathode and cooling the anode are similar to those for the thermoelectric generator, so that fossil-fuel heat sources and nuclear reactors with external thermionic generators are unattractive. Degradation of the thermal energy is particularly inadmissible for thermionic generators in view of the steep efficiency-temperature characteristic. The thermionic nuclear fuel element offers the best prospect of economic power, since the cathode is either the fuel itself or in close thermal contact (*13*). Since thermal energy is rejected at a relatively high temperature (the anode can operate at temperatures in the range 400 to 800°C with negligible back emission) a combination cycle with either steam turbo-alternator plant or thermoelectric generator is attractive. In the latter case the thermoelectric material would be incorporated in the nuclear fuel element.

Research is directed principally towards the attainment of high cathode and low anode work functions in suitable materials, low cathode emissivity to reduce the radiative heat loss and methods of eliminating the space charge. The experimental work already completed in the USA indicates that usefully high efficiency and specific power output will be achievable. The in-pile tests (*10*) are encouraging. Considerable advances in materials and constructional techniques are required and further work is necessary in establishing theoretically the behaviour of the neutralized space-charge diode.

To be continued

Acknowledgement

The author is indebted to the Directors of C. A. Parsons and Company for permission to publish this article; the opinions expressed are his own.

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Instruments, Electronics and Automation Exhibition

Olympia, May 23–28

Here is NUCLEAR POWER's selection of new equipment arranged as a quick reference guide

SIGNIFICANT and typical of the exhibition is the tendency towards increasing application of data storage and handling to link up with a great variety of standard equipment, ranging from accounting and stock control systems to chemical processing and reactor control. Equipment is designed today to meet all kinds of rigid specifications and has to work at extremes of temperature, is required to 'fail safe', and may have to endure long periods of irradiation. It has to fit into very limited space, must be capable of rapid assembly and facilitate future expansion, run for long periods without maintenance and be able to select accurately various phenomena. Instruments have passed beyond the primary purpose of recording and measurement and are now designed to initiate corrective action without manual control.

Data processing and computing

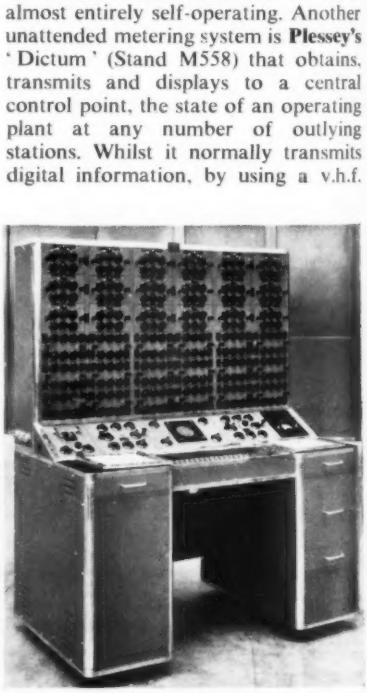
The data acquisition system of **Lintronic** (Stand B55) has been designed to convert the signal-outputs from an analogue simulator into suitable digital form to feed a computer or an X-Y plotter. It scans and digitizes in under 1/10 sec nine parallel signal voltages into binary coded decimals (8-4-2-1) for punching on tape.

Panellit Ltd. (Stand D155) are demonstrating their ISI information and computing system for control applications that need operating, performance and historical data in addition to the ability to carry out sequential control and optimization of plant operation. The 609 scans measurements, received in the form of electrical signals from up to 1000 or more points, and checks that they are at required levels, giving warnings of any dangerous conditions or variation in efficiency. The basic elements of the system include: a solid state, transistorized, computer with magnetic cores for the logics and a ferrite core immediate-access memory; a control unit for converting input signals to digital form with a resolution of 1 in 4096 parts; a high gain transistor feedback amplifier; and a 9-digits electric typewriter that provides a complete log of the measured variables. Visual display at the control console provides information to show identity, value of stored data and functional code identity.

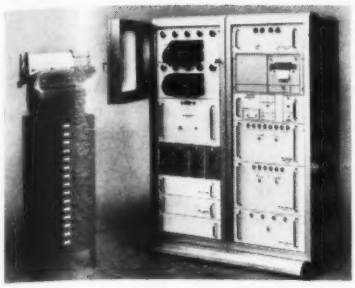
> This year's IEA will be twice the size of its predecessors with nearly 500 exhibitors, over 100 of which are from overseas. It can now be considered to be one of the world's greatest exhibitions of its kind and of particular value to the research and industrial buyer. Equipment being shown now, the results of intensive development through the '50's, will serve for the years ahead, and includes data processing, control systems, radiation appplications and laboratory equipment.

Using data handling modules, **Blackburn Electronics** (Stand Q710) have engineered a data logger that enables continuous monitoring of a number of parameters e.g. from strain gauges, thermocouples, etc., and gives an alarm when any parameter deviates beyond preset limits. The faulty parameter is also recorded either by an output printer or on tape. Type BIE 2114 digital voltmeter covers 1 mV to 1000 V in three automatically selected gauges and has been designed for application in computer inputs and outputs, for reference supply and strain gauge measurements. **Kelvin Hughes** (Stand F257) are showing for the first time a data handling system that is capable of scanning and logging an unlimited number of process variables to an accuracy of 0·1% and at higher speeds than previously available. Standard d.c. input enables application of transducers for applications involving pressure, flow, strain, pulsed and a.c. outputs, with thermocouples serving temperature applications. Information is presented in digital form throughout.

Among the various data scanning systems that are being featured is **Hagan Controls** (Stand M558) Kybernetes equipment which, linked with conventional controllers, can be made almost entirely self-operating. Another unattended metering system is **Plessey's** 'Dictum' (Stand M558) that obtains, transmits and displays to a central control point, the state of an operating plant at any number of outlying stations. Whilst it normally transmits digital information, by using a v.h.f.



GP COMPUTER
—Short



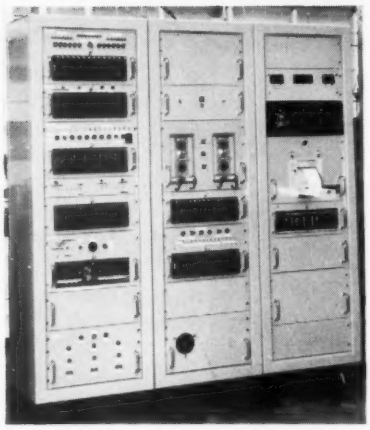
DATA LOGGER
—Blackburn

or u.h.f. radio link it can transmit over ordinary GPO telephone lines. A wide variety of the instruments and accessories that go into data handling systems are being shown by **Ericsson** (Stand D153) and includes digital voltmeters and strainmeters, serializers, translators, trip, operational, and differential input amplifiers and a digital clock, all of which are constructed to carefully designed modules. Complex operations can also be handled by the data acquisition and monitoring equipment, 'Dame', designed by **De Havilland Propellers** (Stand R730) who also have on show an analogue computer for the statistical evaluation of processes that lead to the optimization of controlled variables.

A novel instrument by **Servomex** (Stand F255) is the Field Plotter FP92, an electric resistance analogue using special resistance paper with conducting electrodes. Internal power supply sets up a voltage between the electrodes and across the measuring potentiometer system and, by a probe joined to a galvanometer, the voltage at any point can be measured on the paper, thus preparing a map of the lines of equipotential crossed by lines of current flow. Problems in electrostatics, magnetism, heat flow, fluid flow, etc. can thereby be solved. The multi-point scanning equipment being exhibited by **English Electric** (Stand E215) illustrates the use being made of 'Datapacs', basic logical elements that can be plugged into standard racks and interconnected. Other firms that are demonstrating data processing systems, particularly for temperature, pressure, flow and chemical composition values include **Beckman** (Stand R805) and **Solartron** (Stand E206).

Computers

The 'Lace' MkII analogue computer developed by **English Electric** (Stand E215) will be working out typical problems in heat transfer and chemical filtering processes. The **Elliott** G-Pac MkII centrally patched analogue (Stand D155) which is constructed on a modular basis, has a



DATAPAC SCANNER
—English Electric

system centre that accommodates 10 designated summing amplifiers; 10 summers/summing integrators; 40 ten-turn helical potentiometers; 3 servo-multipliers; and 5 MkI type amplifier positions for the accommodation of any special units required by a particular problem. The central patch panel with removable boards allows a rapid change of problem and provides easy storage. Another analogue computer, the Simlac Minor, of **Short Bros. and Harland** (Stand M557) is a small capacity general purpose instrument with a capacity of 32 amplifiers and 100 passive elements, the entire unit being housed in two 19 in. G.P.O. type racks. An 18-amplifier general purpose computer is also being exhibited. The Model 955 analogue of **AEI** (Stand E213) which solves linear and non-linear differential equations, can be used for the study of the dynamic performance of physical systems by means of 'patch-cards' set up across the front of the computer.

In the digital field, **Ferranti** (Stand N604) will be showing the desk size Sirius, which can solve a set of 27 simultaneous equations in 6 minutes; and Argus, designed for the real time control of a variety of processes requiring many parallel input and output channels. A ferrite core has a basic capacity of 1024 words. **Standard Telephones** (Stand K459) have a completely transistorized digital computer based on the Zebra computer which has fast multiplication with operation time of 624 micro-secs; additional main store registers with immediate access ferrite store in blocks of 512 words up to 2048 words, and immediate access registers. The magnetic tape input/output works at the rate of 20,000 characters/sec whilst the paper tape input/output reads at 800 characters/sec. **EMI** (Stand D166) will be demonstrating both their Emiac II analogue computers and the Emidec 1100 and 2400 digital machines.

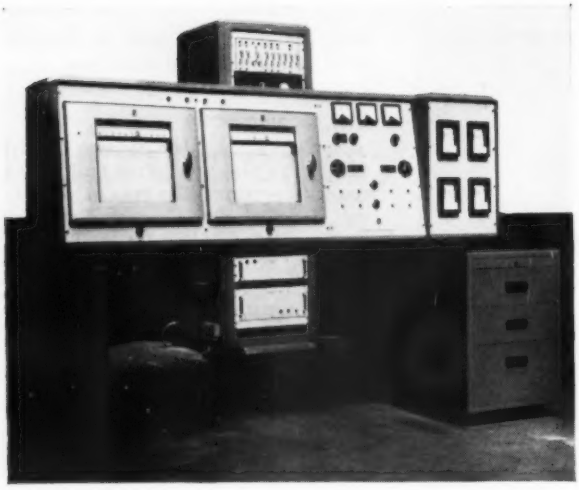
Reactor simulators

Analogue computers are also having a special application in the training of reactor operators. The reactor simulator designed by **General Precision Systems** (Stand M560) for the Harwell Reactor School has a power range from 1/10 watt to 1000 MW. Reactor kinetic equations are transposed and computed in logarithmic form enabling the 10 decade power range to be covered without a break and with equal sensitivity in each decade. Accuracy is therefore constant at high and low powers. Another simulator for solving operation equations is that being exhibited by **English Electric** (Stand E215) for use at its Atomic Power Division at Whetstone.

Reactor control

A complete control rod mechanism designed for one of the CEGB nuclear power stations is being shown by **Elliott Nucleonics** (Stand D155) whilst a rod drop recorder is to be seen at **Cambridge Instruments** (Stand F259). This is a remote position recorder for the functional testing of shut-down rods. Any difference in position between the rotor of the transmitting magslip attached to the control rod, and the rotor of the receiving magslip fitted in place of the recorder slide-wire, is fed as an error signal into the amplifier, driving a servomotor and the receiving rotor towards balance.

AEI (Stand E213) will demonstrate a burst cartridge detection computer of the type being installed at Berkeley. It analyses the output from scintillation counters used in the gas monitoring system and can memorise the previous 48 counts from each of 400–600 channel groups. The temperature scanning equipment of **Marconi Instruments** (Stand D157) that is being provided for Hinkley Point scans and measures, at the rate of five points per second, 600 thermocouples. The output for the switching unit is fed into a digital voltmeter handling outputs as low as 20 millivolts full scale with an accuracy of $\pm 1\%$. Digitized information is stored on a magnetic drum and any readings that fall outside the preset range operate an alarm warning, at the same time printing automatically the measured value. A burst cartridge detection unit is also to be seen, consisting of a scintillation counter which feeds a ratemeter, the resulting information from which is displayed on an Elliott 72-point recorder. The ratemeter, TF1292, provides a count-rate range of 30, 100, 300 and 1,000 per second full scale, whilst the inte-



REACTOR SIMULATOR —General Precision

grated-count ranges are 1,000, 3,000, 10,000 and 30,000 counts full-scale. When monitoring the coolant gas, any ionized radioactive particles are precipitated on to a wire fed with an attracting e.h.t. voltage provided by the ratemeter.

For the provision of visual and aural warnings of "off-normal" conditions in reactors, **Panellit** (Stand D155) have a series of 'Panalarm' annunciators. The actuating switch can take the form of either a thermostat, float switch, pressure switch, relay or any other device that will make and break an electric circuit.

Radiation instruments

Unitized Nucleonic Equipment that can be used in a wide variety of applications ranging from geiger counting to pulse counting in reactor control and measuring channels, has been developed by **Ericsson** (Stand D153). Built on the sub-unit principle, type 200A comprises 24 units, each designed for a specific function. Other multi-purpose equipment is being shown by **Airmec** (Stand D162) and includes radiation monitors type 1021B and type 255 and a general purpose counter 1339A. Type 1021B has a beta-gamma probe unit employing a geiger tube with an alpha probe unit containing a photo-multiplier tube. Measurement ranges in four stages from 0 to 2,000 counts/sec. Type 255 which is transistorized, battery operated and portable, is fitted with four probes, a sample holder and lead castle in addition to a built-in geiger tube for survey work. The basic equipment of the GP counter consists of a power supply unit and a scaling unit made up with a slow scaler sub-unit and a paralysis/timing sub-unit. As accessories, a quenching sub-unit is provided for use with geiger counters for beta-gamma counting and an amplifier discriminator sub-unit for alpha counting with scintillation type probes. A fast scale sub-unit may also be provided when the sample disintegration rate is high.

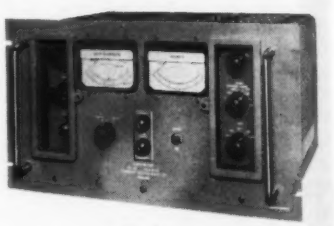
The determination of C14, H3 and S35 radioactive measurements is possible with the Cary vibrating reed electrometer of **B & K Laboratories** (Stand E203). It can also be used for pH determination and mass spectrometry. **Burndept** (Stand B68) have a varied range of nucleonic instruments: BN110, a radiation monitor ratemeter using geiger and scintillation counters; a portable 1407C fast neutron monitor employing a proton recoil chamber; BN120 universal scintillation counter that can be adapted for narrow or wide beam collimation; and BN131, an industrial radiation switch operated by beta or gamma radiation, used for level control and counting where a normal capacitance switch would be inoperative.

A range of radiation monitoring equipment displayed by **Ekco** (Stand E208) represents the type of instruments employed by the Radiation Monitoring and Tracer Service. Automatic scaler N610 used with type 664 universal scintillation counter gives an overall resolution of 1 microsecond and has an automatic pre-set time and count referred to a stable time signal generated internally. Model N664 is a shielded bench-standing instrument for 'in vitro' counting of millimicrocurie quantities of beta and gamma emitters. A stainless steel contained lightweight scintillation counter, N618, can be cold sterilized and is suitable for medical use.

The latest addition to the SC series of scintillation counters from **Panax** (Stand S870) is an improved light tight shutter that enables samples to be changed in normal room lighting. At 5°C efficiencies of 95% for C 4 and 36% for tritium have been obtained with backgrounds of 400 and 600 c.p.m. The USC series of scintillation counters have been extended to cover well counting, end-on counting, annular sample counting, end-window counting using planchets, liquid flow and directional counting. All parts which can be used in the Universal Castle type LC/3 are interchangeable and are designed around one standard photomultiplier assembly. In addition, there is a high sensitivity gamma probe G120H3 that can locate sources of only 1 microcurie located at a distance of 1½–3 ft; counters SA100 and 102 containing a two-decade scaler; and a fully automatic instrument AC300/6 with count and timing channels each having six plug-in Dekatron units giving a range of pre-set counts up to 10^6 counts, and pre-set time up to 10,000 seconds for timing pulses of 100 pulses/sec.

20th Century's range of neutron counters (Stand Q713) includes a miniature fission chamber capable of high temperature operation up to 1000°C and a flat type suitable for neutron beam measurement; type RC6 and 7 ionization chambers with enriched boron for increased sensitivity; an in-pile ionization chamber of the mean current type that will pass currents of 1 MA in a flux of 10^{13}n/cm²/sec; and a series of x-ray proportional counters covering energies from 1 KeV to 120 KeV.

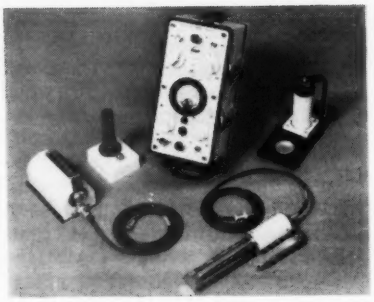
For the location of radioactive minerals, **Hendrey Relays** (Stand C113)



TF192 RATEMETER —Marconi

SA102 SCALER —Panax

TEMPERATURE SCANNING
—Marconi



RADIATION MONITOR
—Airmec

are introducing their gamma survey borehole logging equipment 1417A which includes a gamma geiger counter in a $\frac{3}{4}$ in. probe unit; a $1\frac{1}{4}$ in. probe containing a larger sensitive geiger, the sensitivity of which is about 3·7 that of the former; and a field ratemeter 1368A for indication of gamma flux intensity. **Electronic Instruments** (Stand Q711) are also showing a gammagraph which gives continuous recording of background radiation and will operate unattended for periods up to one month.

Pulse instruments

The Nucleonic Test Set N107 of **Dynatron** (Stand E208) consists of a combined double pulse generator and measuring oscilloscope providing the necessary services for maintenance of pulse amplifiers, scalers, ratemeters and pulse analysers. The twin channel pulse generator designed by **Marshall** of Cambridge (Stand B63) produces a prepulse and two subsequent main output pulses. Width, amplitudes rise-time and sign of the main pulses are independently selected in the two channels whose only common property is repetition frequency. **Panax** (Stand S870) also have a pulse generator, type G100H, that provides single and double pulses (with repetition rates of 2, 20, 200 and 100 c/sec) for testing and adjusting scalers, ratemeters, amplifiers, paralysis and coincidence circuits. **Dawe** (Stand Q727) will be exhibiting a type 412 pulse generator.

English Electric's range of pulse modulators include hydrogen thyratrons and tetrodes for radar applications (Stand E215). Their 6 MW power klystron K352 is for linear accelerator application. An improved version pulse amplifier, model 4250H, of **Panax,** used with counters type SC, is intended for low energy beta counting and for most other types of scintillation counting when used with the USC series.

Dynatron's single channel pulse analyzer, type N102, designed for use in spectrometry, comprises a fast threshold amplifier, followed by two discriminators, giving an output pulse when the lower discriminator only is triggered. Output may be fed to either a scaler or ratemeter. The pulse height analyzer, HS100, of **Marshall**'s accepts positive or negative pulses at a maximum rate of approximately 1600 pulses/sec sorting them into 100 or 150 channels. Information is stored in a dynamic memory capable of holding 2400 binary digits in two torsional delay lines, display of digital information or analogue spectrum appearing on a cathode tube. The magnetic pulse recorder, MPR103, for use with pulse analyzers, records on two tracks simultaneously, allowing several different spectra to be recorded on one track with identifying pulses on the other; or recording coincidence spectra, an application that enables experiments using one 100-channel Kicksorter normally requiring 100 such instruments. Another pulse height analyzer, PHAIII, is that of **AEI** (Stand E213).

Instruments for measurement

Many systems have been developed that not only measure the variations in physical phenomena but convert them for the purpose of operational control. The new series of transistorized electronic 'Consotrol' instruments of **Foxboro-Yoxall** (Stand E202), for instance, of solid state construction can be used as recorders and controllers for flow, pressure and temperature. Apart from differential convertor-transmitters for flow and liquid level, **Honeywell** (Stand E200) have the 'Electrik Tel-O-set', a miniature system of transmitters, recorders, controllers, transducers and final control elements. **Beckman**'s (Stand R805) range of digital instrumentation converts values of unit time, frequency, time intervals and other phenomena, into rpm, pressure, temperature, strain and flow. The 'Sensaire' temperature transmitter of **Taylor Controls** (Stand D161) converts temperature, measured by a mercury filled thermal system, into a proportional 3–15 psi air output pressure for flow, liquid level, pressure or density of fluids.

Temperature

Among the less elaborate exhibits are the recent thermocouple developments of **Engelhard** (Stand N606). The 'Integral-Sheath' has a flexible metallic outer covering, $\frac{1}{16}$ in. dia., with a pure oxide refractory for insulation; a 'Fibro' platinum element with good mechanical properties up to 1600°C; and for use up to 2800°C: iridium v 60%–40% rhodium and tungsten v tungsten-rhenium thermocouples. A resistance spear thermometer developed at the **DSIR** Torry Research Station (Stand E214) responds ten times as fast as a mercury thermometer. It operates on the variation of the resistance of a small copper coil contained within the tip of a hypodermic needle, effecting indication by means of a calibrated dial attached to a variable resistance that forms a simple Wheatstone bridge, one arm of which includes the coil. An electronic strip-chart recorder of **Kent** (Stand D159), 'Multelec' Mk3, has the same components and system as the 'Commander KE' circular-chart recorders and can be used with thermocouples, resistance thermometers, and radiation pyrometers. A wide range of instruments are also being shown by **British Rototherm** (Stand Q729), **Nottingham Thermometers** (Stand L509), **Coley Thermometers** (Stand Q708F) and **Newport Instruments** (Stand Q715) who have designed a circular chart recorder for slowly changing values.

The **Cambridge** electronic recorder (Stand F259) is a self-balancing potentiometer, bridge or current balance measuring, recording and controlling any quantity that can be converted into a suitable d.c. signal. The electropneumatic 'Numulac' programme controller which has been designed to record temperature and pressure variables can be fitted-up to two Bourdon type measuring systems. In the pocket size range is the 'Minican'; suitable for temperatures of −30° to +160°C, recording on a 40 mm chart that revolves at a constant speed for 2, 12 or 24 hours. **Evershed** (Stand K458) have a new transmitting resistance thermometer which generates an output signal suitable for indication and/or recording for direct application to a Mk4 process controller. Another electronic resistance thermometer is the 3510 of **Fosters** (Stand C111) that has now incorporated a deviation indicator calibrated in terms of °C or °F showing, at any instant, the actual deviation in degrees from the control point, within the limits of ±25°C or

±5°F. In the indicating and control field is the 'Teloscale' 4141, a self-setting instrument that allows temperature measurement of several different metals at one point, or at several widely separated measuring points, each with an interlocking push-button switch. The 'Multi-point scanner' designed by **West Instruments** (Stand H354) for the continuous monitoring of the temperatures of up to twelve successive positions, uses thermocouples or a resistance bulb for its sensing, control for automatic shut-down being effected if maximum temperature is exceeded. Resistance bulbs are also used in the **Fielden** (Stand C110) range of transistorized temperature instruments. In addition to a completely sealed controller, there is the multipoint temperature indicator intended as a simple system for use with thermocouples. Other companies exhibiting in this field are **Winston Electronics** (Stand M564), **Zeal** (Stand L504) who are concentrating particularly on electric contact thermometers for the temperature control of water and air; **Plessey** (Stand M558) with a Hagan thermostat developed for measurement and control in large ducts at continuous working temperatures up to 1400°; **Graviner** (Stand R827); **Ether** (Stand E205); and **Winston Electronics** (Stand M564).

Pressure, flow and level

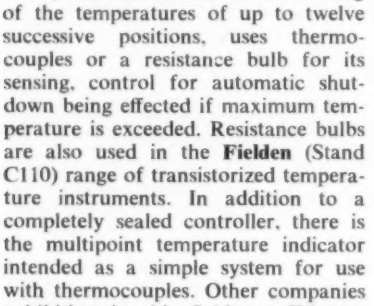
A relative newcomer to the range of pressure and vacuum recorders is the Arkon 1602 flow recorder of **Walker Crosweller** (Stand Q700) for high pressure gas, compressed air, steam and water. **Dewrance** (Stand M554) have a new design Ashcroft pneumatic indicating pressure transmitter actuated by a Bourdon tube system that has an output pressure of 3–15 psig capable of transmitting up to 1000 ft. Their Microsen process control system which transmits temperature, flow and liquid level as well as pressure consists of three term recording or indicating controllers, single or two pen recorders, electro-pneumatic transducers and a ratio amplifier control. For recording pressures up to 20 in. WG and from 0–3000 lb/in², **Plessey** (Stand M558) have an instrument that can be also used for telemetering or control. **Normalair's** switches (Stand R826), working over a pressure range of up to 1 atmos., have been designed to close an electrical circuit on change of pressure.

Recent among leak detection equipment is a new design mass spectrometer of **20th Century** (Stand Q713) that has an integral high speed pumping unit capable of dealing with volumes up to 100 litres without ancillaries. **AEI**'s leak detector (Stand D152) comprises a type V1984 diode and control unit R2276 giving sensitivity of the order 10^{-8} litre micron/sec. The diode is a thoriated tungsten filament device readily poisoned by oxygen and the drop in emission is used to detect entry of the gas into the system under test. Other equipment is being shown by **Elliott** (Stand D155).

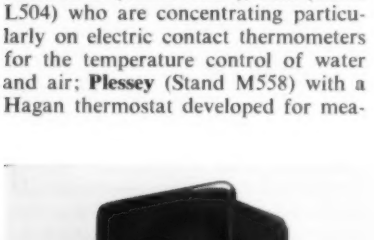
Differential pressure systems for flow measurement are represented by **Honeywell** (Stand E200) and **Fischer & Porter** (Stand A10). The latter also have high capacity/high pressure flowrators, an ori-flowrator shunt type meter and the model 585 'Thruflow' transmitting flowmeter. A Barton differential pressure unit is used with the **AEI** flow recorder that has a 12 in. circular chart and can be applied to noxious gases and corrosive fluids. **de Havilland's** electronic 'Pottermeter' (Stand R730) incorporates an hydraulically-positioned bearingless rotor making it suitable for any liquid and any size of pipeline. **Gilbarco** (Stand G302) have a large range of Brodie-Kent positive displacement meters and, among their flow control valves, is the Model GN 104A remote presetting control which ensures automatic indication of flow failure or overrun.

For the testing of air and flue gas systems, **Airflow** (Stand B66) have developed a completely portable airflow measurement outfit. The turbine flow meter of **Leeds** (Stand J401) totalizes over a wide range and is suitable for both chemical and industrial liquids. An interesting design for the distant reading of air flow is the rotating vane meter of **Casella** (Stand K460) where light falling on a photocell is periodically obscured by the vane during rotation thereby producing a pulse from the cell which is fed by a screened cable to frequency meter. Four ranges of air speed are possible up to 100 ft/sec.

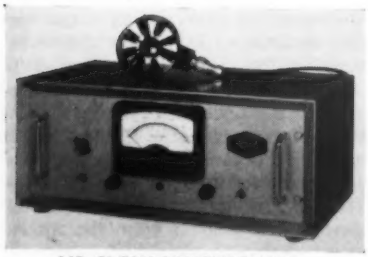
For level detection where sealed containers are concerned, radiation sources are increasing in use. The **Panax** (Stand S870) model TR56L uses a caesium source and has adjustable sensitivity; **Ekco**'s new gauge N663 is suitable for clamping to pipelines and tanks (Stand E208). Their nucleonic equipment also includes a



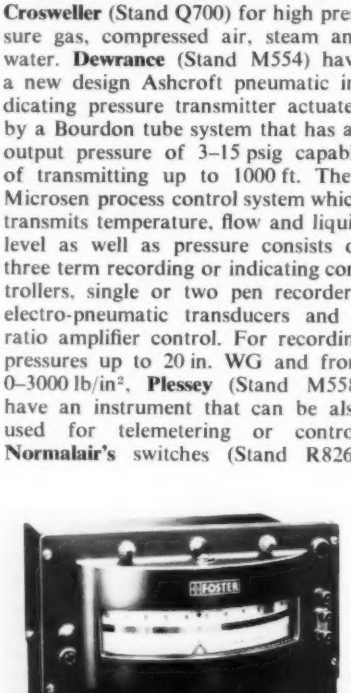
CIRCULAR RECORDER
—Kent



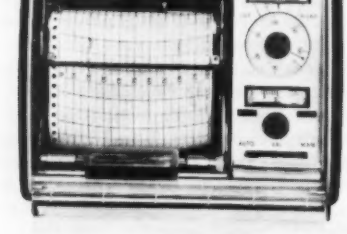
MULTELEC RECORDER
—Kent



AIR FLOW MEASUREMENT
—Casella



TEMPERATURE CONTROLLER
—Foster



RECORDER CONTROLLER
—Foxboro

new moisture gauge. Using an optical system, **Normalair** (Stand R826) have developed a liquid level senser for a wide variety of fluids. Another variation is the stainless steel vibrating probe of **Firth Cleveland** (Stand H353) where oscillation is damped by contact with a liquid or semi-solid, the suppression operating a relay. The Gilbarco-Firth electronic tank contents gauge measures liquids to an accuracy of within $^1/_{16}$ in. or for laboratory use, $^1/_{64}$ in. **KDG Instruments** (Stand K457) also have electrical instruments for tank measurements.

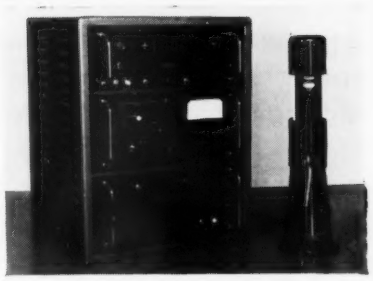
Testing materials

The presence of flaws in fabricated metal parts can be achieved by ultrasonic means. The Mk.III detector of **Ultrasonoscope** (Stand A3) uses a 5 in. flat-faced cathode ray tube and a wide range of single, double and combined probes for on site inspection of welds, plate and other parts. Thickness checking is also possible particularly when only one side of the specimen is accessible. The new portable Mk.II detector, with an operating frequency range of $\frac{1}{2}$ Mc/s–10 Mc/s and maximum depth range of 20 ft (in steel), is fitted with a contrast control to enable small defect echoes to be compared against echoes received from grain boundary conditions. The **Sperry** (Stand C101) 'Introview' detector, which was primarily designed for testing stainless steel tubing, has been adapted for conducting tests on manufacturing defects of low conductivity by the addition of h.f. converters and probes. Radiation sources are extremely adaptable to the gauging of thickness in materials. The **Burndept** (Stand B68) BN119, a portable battery-operated instrument, determines thickness of zinc plating on a steel base. **Ekco's** (Stand E208) nucleonic equipment includes the N582 auto-standardization thickness gauge which automatically checks every half-hour the measuring heads and corrects for contamination by dust and oil. The single-channel gauge N565, used with an extension meter and auto control unit, ensures accurate control of a coating machine of up to 12 millionths of an inch. Inspection of objects to an accuracy of 0·001 in. is possible on the **Ferranti** machine (Stand N604) with the aid of electro-optical sensing units. Measured information is displayed continuously on two 5-figure electronic counter banks. A combined creep and fatigue tester has been developed by converting a commercially available creep machine. **BISRA** (Stand E214) demonstrate how it is now possible to predict the behaviour of metals under combined static and cyclic stresses.

Analysis

Automation has come to chemical analysis. The 'AutoAnalyzer' of **Technicon** (Stand P653), by means of a continuous and dynamic flowing reagent system, which can operate also as a separate analytical entity in the chromatographic set-up, accurately handles either the full stream delivery of the column effluent or any part thereof. Automatic analysis is also possible with the 'Analmatic' equipment of **Baird and Tatlock** (Stand N603). A burette type autotitrator, used for the determination of dissolved oxygen, employs a burette with an automatic meniscus finding mechanism and a titrant normality compensator. **Doran** (Stand S858) have a similar instrument, the M4910, that is arranged for rising or falling titrations both in pH units and millivolts. An electronically controlled photoelectric instrument by **Ericsson** (Stand D153), the ETL-NPL automatic polarimeter 143A, has a basic sensitivity of 0·0001° arc and a range of 0·05° arc from any preset position of its polarizer. Monochromatic light is provided by a metal dielectric filter which may be changed as required. Equipment for automatic x-ray analysis is being shown by both **Solartron** (Stand E206) and **Research & Control** (Stand D164).

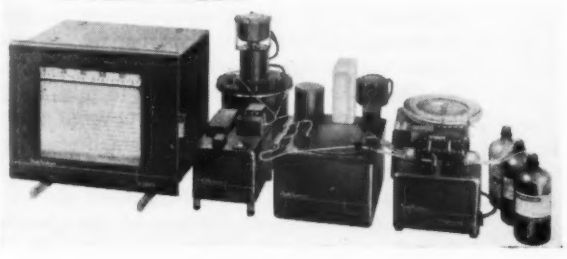
Gas analysis by infra-red is a speciality of **Grubb Parsons** (Stand P651). To meet the need for a simpler and cheaper equipment, the DM2 single beam model gas analyzer has been developed in which prism and grating are automatically coupled over the entire spectral range. Slit programming is provided to maintain the energy constant to ± 20%. The DM3 monochromator employs two interchangeable gratings and covers the range 2 to 20 with one break at 5 where the gratings are changed over. The 'Spectrosorter' is a fixed wavelength analyzer incorporating a grating monochromator with indium antimonide detector.



AUTOMATIC POLARIMETER
—Ericsson

The latest gas chromatography units of **Griffin & George** (Stand R803) include the VPC Mk.IIB for the katharometer method of component detection; and the VPC-flame ionization unit 'Chromatrac' which measures continuously constant changes in a gas or liquid stream. The analysis of gases by a thermal conductivity meter is the basis of the helium-in-air analyzer of **Cambridge** (Stand F259). **Kent** (Stand D159) employ a similar principle in their equipment for analytical measurement of CO_2 and SO_2. **Engelhard's** (Stand N606) Hersch oxygen meter detects and measures continuously traces of molecular oxygen in gases with a range of 0–10 and 0–100 v/min. The 'Deoxo' range of instruments includes an indicator for traces of 1% oxygen and 2% hydrogen; a pure dry hydrogen producer; and a producer of pure nitrogen with a controllable hydrogen content. The continuous recording of oxygen content is provided with the **Servomex** (Stand F255) oxygen analyzer DCL83 in which test gas is passed into a non-uniform magnetic field, oxygen being attracted into the field thereby exerting a force on the test body.

Other interesting developments in the field of analysis include a three dimensional microscope, **DSIR** (Stand E214), where the image is built up by vibrating the focusing mechanism; a new Abbe refractometer of **Bellingham & Stanley** (Stand G315); and a range of spectrum analysers from **Winston Electronics** (Stand M564) and spectrophotometers from **Beckman** (Stand R805).



AUTOANALYZER
—Technicon

The third article of this series discusses the design and use of apparatus for the measurement of radioactive contamination

Health physics instrumentation—3

by DENIS TAYLOR, M.Sc., Ph.D., M.I.E.E., F.Inst.P.,
Plessey Nucleonics Ltd.

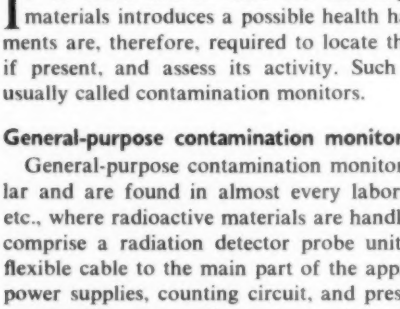
IT IS WELL KNOWN that the handling of radioactive materials introduces a possible health hazard and instruments are, therefore, required to locate this contamination if present, and assess its activity. Such instruments are usually called contamination monitors.

General-purpose contamination monitors

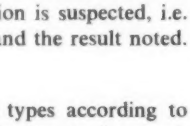
General-purpose contamination monitors are very popular and are found in almost every laboratory, workshop, etc., where radioactive materials are handled. The monitors comprise a radiation detector probe unit connected by a flexible cable to the main part of the apparatus, where the power supplies, counting circuit, and presentation unit are housed. The presentation unit may be a deflexion meter, a recorder, an electromechanical register, or an aural device such as a loud speaker. The detector is moved over the area where the radioactive contamination is suspected, i.e. this area is scanned with the detector and the result noted.

Probe detector units

The probes are of several different types according to the nature of the radioactive contamination to be monitored. It is possible, however, to use a combination probe for a number of purposes, either simultaneously, or in succession with just a small alteration to the probe or to the associated circuit. One form of this probe for beta- or gamma-radiation monitoring is shown in Fig. 1. The detector in this case is a thin glass-wall tubular geiger counter, the glass wall being of the order of 30 mg/cm², which is sufficient for monitoring beta-emitters with a maximum energy in excess of 0·5 MeV. For monitoring low-energy beta-emitters, the end-window type of geiger counter should be used which involves a different type of probe construction. This is shown in Fig. 2. It may be noted that using a geiger counter with a window thickness of 3 mg/cm² allows (*1*) the monitoring of beta-emitters with a maximum energy in excess of about 0·15 MeV.



Probe used for beta- or gamma-radiation monitoring (Fig. 1)



Probe construction used for end-window type of geiger counter (Fig. 2)

Referring again to Fig. 1, it can be seen that the geiger counter is contained in this case in a cylindrical probe with a window on one side which may be opened or shut. With the window opened the probe can be employed for monitoring both beta and gamma-radiation. With the window closed only the gamma-radiation can penetrate to the counter and the system is then only sensitive to gamma-radiation. The presence of beta-radiation can, therefore, be ascertained by simply noting whether there is a change of reading of the instrument when the window is opened.

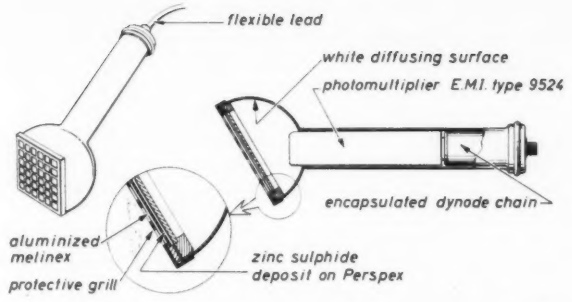
The thickness of the cylindrical metal tube housing for the probe is a matter of some importance. Obviously it must be sufficient to prevent the penetration of the hardest beta-emitters to be monitored. If beta rays of maximum energy of 5 MeV are the hardest to be monitored, a wall thickness of 3000 mg/cm² is appropriate.

Another example of a combination system is illustrated in Fig. 3. In this system a scintillation counter is employed, comprising a plastic sheet covered with 12 mg/cm² of ZnS–Ag and viewed by a photomultiplier, and it is used to provide simultaneous counting of alpha- and beta-particles, separation being obtained by amplitude discrimination (*2*). Sandwich crystals of this type are finding application to a number of special purpose monitors, apart from their application to general-purpose monitors.

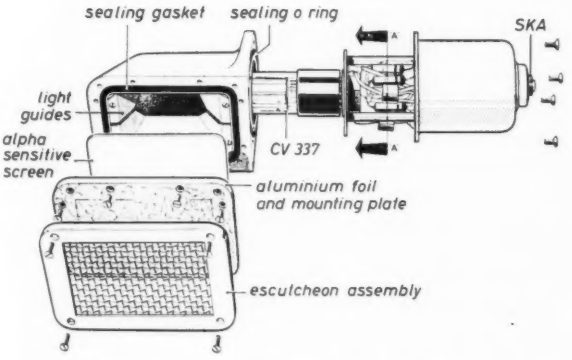
Apart from these multipurpose detector probes, probes are, or can be, employed for a number of specific purposes. For example, a variety of scintillation counter probes have been designed for these general-purpose contamination probes. For alpha-activity monitoring it is usual to use a scintillation counter probe comprising a zinc sulphide screen, a light prism and a photomultiplier tube, the whole being mounted in a light-tight box. One type of construction adopted by the UKAEA (*3*) is shown in Fig. 4. The window of the unit must be sufficiently thin to allow the passage of the alpha-particles on to the zinc sulphide screen, and AERE for many years found it convenient to use aluminized nylon of about 0·7 mg/cm² for this purpose. Each alpha-particle striking the zinc sulphide screen produces a light scintillation, which is detected by the photomultiplier, and the output from the photomultiplier is counted in the counting-rate meter circuit in the main unit. The design of the window is of considerable practical importance in these probes. At the present time it is customary to use two thin sheets of aluminium foil. Although each sheet by itself may have a number of small pin holes, the two together can be light-tight and still remain within the limits of transparency required. It is to be realized, however, that the window is a fragile component, and in the UKAEA laboratories a very high percentage of the total faults experienced with this class of instrument is due to perforation of the window system. Many designs of these alpha probes (and the corresponding alpha/beta detectors) have, therefore, been suggested which permit the easy and quick replacement of the window. The majority of these depend on the window being integral with the phosphor and light guide and replacing this complete when a perforation has been experienced. It is fair to say that no one has made a complete success of their solutions to this problem, and there is, therefore, still room for new ideas to the solution of this problem.

Another detector-probe in wide-scale use in these general-purpose contamination monitors is the gamma-sensitive scintillation probe. This is shown in Fig. 5 and comprises a sodium-iodide scintillator (thallium-activated) mounted on the end of a photomultiplier tube. The probe unit also contains, in this case, the dynode resistor chain (for providing the various voltages for the operation of the photomultiplier tube) as an encapsulated unit including the photomultiplier tube base. A collimator is provided in this case, and it is often an advantage to provide a set of caps with central holes of different diameters. These may be clipped over the scintillator to provide collimation of the radiation being monitored. In some cases (e.g. hospital use) it is to be remembered that the probe must be kept scrupulously clean (i.e. radioactively clean) and this may be best done perhaps by enclosing the probe in a thin polythene bag when in use in circumstances when contamination is possible, the bag being replaced when necessary. However, it is a good principle to design the probe itself so that surfaces are as smooth as possible so that its decontamination, if it is necessary, is a simple operation.

The size of the scintillator is a matter of importance, and by the use of larger area scintillators (*4*) higher sensitivity can be obtained. The thickness of the scintillator must be chosen to be appropriate to the radiation to be detected. The scintillator shown in Fig. 5 is that appropriate to the detection of very low energy gamma-radiation. For a general-purpose instrument a much thicker phosphor would be appropriate. Generally it should be remembered that the thickness (*5*) should be such that the incident photon gives up the whole, or at least a large fraction of its energy in passing through the scintillator.



A combination system using a scintillation counter viewed by a photomultiplier (Fig. 3)



Scintillation counter probe for alpha-activity monitoring used by the UKAEA (Fig. 4)

Smear tests

As already noted the main unit of a general-purpose contamination monitor comprises a pulse amplifier, a counting-rate meter and power supplies. In some cases an alternative presentation unit is provided which may take the form of an aural indicator, e.g. a loudspeaker unit, or an electromechanical register. Both these presentations are particularly useful in monitoring very low activities, in the one case the counts per unit time have to be measured by actual counting of the clicks. In the other case the discharges of the detector are registered and the counts in the measured time are available for inspection.

As electromechanical registers are now available which may be operated at up to, say, 25/s, this system is obviously more versatile than loud-speaker indication and is to be preferred perhaps when smear test samples are to be monitored. Smear tests are employed to determine the presence of loose contamination. This involves rubbing a piece of blotting paper over the suspected area and then determining the presence of any radioactive contamination rubbed off by placing the paper under a suitable radiation detector. In practice, this means a double measurement, because of the presence of background radiation, due to

local radioactivity and cosmic rays. This means that it is necessary to carry out a preliminary experiment to determine the background counting rate (N_1) without the blotting paper in position beneath the detector, and then repeat the measurement with the blotting paper in position. In the second case the counting rate (N_2) is due to the radioactive contamination on the blotting paper and the background, and hence the counting rate due to the contamination on the blotting paper as a result of the smear test will be $N_2 - N_1$.

It is necessary to realize also how to calculate the activity on the paper from the measured counting rate. This involves first arranging the detector in a standard position with respect to the source (i.e. the blotting paper) to ensure constant reproducible and perhaps known geometry. The relationship between the activity (N) and the measured counting rate (n) is of the form

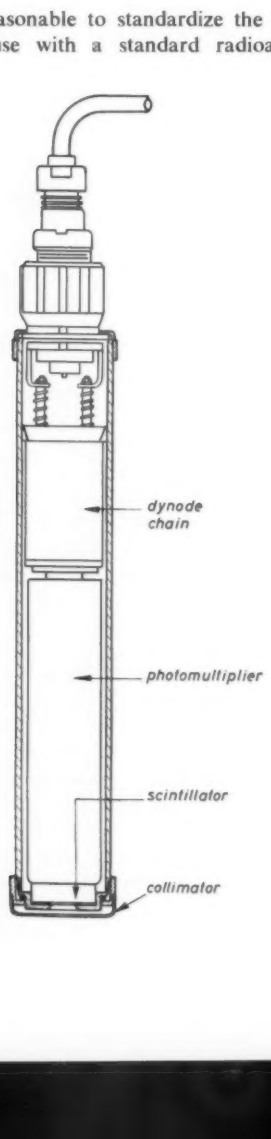
$$N = \frac{R}{\eta\varepsilon} n$$

where η is the geometrical efficiency of the counting arrangement, ε is the detection efficiency of the system and R is a constant which takes account of the actual experimental arrangement. For a standard experimental set-up

$$N = kn$$

where k is an overall constant of proportionality for the type of radioactive source in question and the experimental arrangement.

In most cases it is reasonable to standardize the measuring system before use with a standard radioactive source, i.e. one whose activity is known, of the particular isotope to be monitored and in the same geometry. This means determining the constant k, so that by determining n experimentally the activity N can be computed in disintegrations per second, or in microcuries by dividing the result by $3{\cdot}7 \times 10^4$.



Gamma-sensitive scintillation probe used in general-purpose contamination monitors (Fig. 5)

If a contamination monitor is to be designed for smear tests and for general monitoring purposes, it is essential to consider this from the beginning. In general, it means providing the monitor with:

1. facilities for measuring very low counting rates when necessary,
2. facilities for checking smear test samples under conditions of constant reproducible geometry when necessary.

The latter may also involve the provision of lead housings to ensure constant low-background conditions of measurements when smear test samples are to be checked. Hence, general-purpose monitors are not only provided with a variety of detector probes for general monitoring purposes, but with a number of special laboratory set-ups for checking the activity of smear-samples.

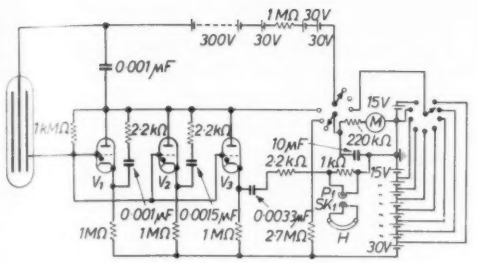
Electronic circuits

The electronic circuit used for these general-purpose monitors varies very much from one instrument to another. Thermionic valves are gradually being superseded in these circuits, first by cold-cathode tubes and more recently by transistors. Fig. 6 shows a typical counting rate meter circuit using cold-cathode tubes. In this case three cold-cathode tubes are employed and by adjusting the time constants as shown, a counting rate of 1200 counts/min gives one-quarter full-scale deflexion, whereas full-scale deflexion requires about 36,000 counts/min. The 135 V section of the battery which is used for operating the cold-cathode tubes is subject to a current drain equal to the current passed by the indicating meter, and its life, therefore, depends on the average gamma-ray intensity to which the instrument is subjected.

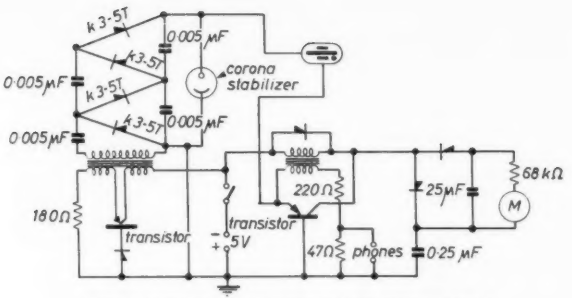
As indicated above transistors are, in many cases, being employed in counting-rate meter circuits. They offer the advantages of small size and low power consumption. One simple form of circuit is shown in Fig. 7. The power supply comprises four miniature Mallory cells producing a total of 5·4 volts, which is sufficient to operate directly the transistorized ratemeter circuit. The radiation detector is of the low-voltage g.m. counter operating at a maximum of 420 V which is supplied by a transistor oscillator feeding a Cockcroft-Walton voltage multiplier and metal rectifier. Both meter indication and aural indication are provided with this circuit.

W. G. Spear (*6*) has given transistorized circuits for general-purpose contamination monitors. It is interesting to note that his instrument for alpha or beta-gamma monitoring weighs 2·5 lb, whilst his gamma or beta-gamma scintillation-counter instruments weigh 4 lb each. All these instruments show a longer battery life and have a volume and weight about half that of comparable instruments using thermionic sub-miniature valves. Further details of transistor circuits are given in papers by F. S. Goulding (*7*), J. Labeyrie (*8*), G. D. Smith (*9*), and E. H. Cooke-Yarborough (*10*).

A word or two must now be said about the scale of measurement required. For alpha-activity measurements,



Counting-rate meter circuit which uses cold-cathode tubes (Fig. 6)



Simple transistorized counting-rate meter circuit (Fig. 7)

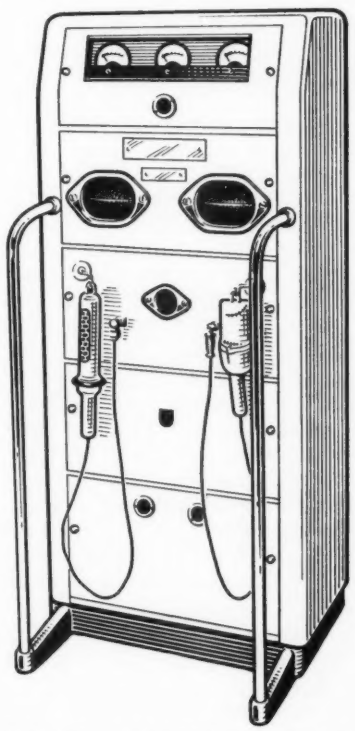
measurement down to 10^{-5} microcurie/cm²,* if the sensitive area of the alpha-probe is A cm² and the efficiency is ε, then we have with this level of contamination $10^{-5} \times 3{\cdot}7 \times 10^4 \times A \times \varepsilon$ counts/s over an area of A cm². A is usually about 35 cm² and ε about 10%, and therefore the level of contamination corresponds to about 1 count/s above background. The background with this type of counter is generally well below 1 count/s and so usually 10^{-5} microcuries/cm² is easily measurable.

With β-contamination the corresponding contamination level* is about 10^{-4} microcuries/cm². The usual type of probe described earlier (see Fig. 1) has a background counting rate of about 2 counts/s, and 10^{-4} microcurie/cm² gives a counting rate of about 5 counts/s above background with the probe about an inch or so away from the surface being monitored.

For all the above reasons general-purpose contamination monitors are usually provided with a number of linear scales covering the above levels with a loud-speaker (or electromechanical register display) for dealing with very low count rates. One form of instrument which has proved very popular is provided with four ranges 0–2, 0–20, 0–200 and 0–2000 counts/s. A logarithmic scale instrument covering a range of 0–500 counts/s is beginning to be employed and it will be noted that this type of scale provides high sensitivity at low counting rates which is a requirement. The use of a simple logarithmic scale is probably preferred on the basis that as no range-switching is involved there is less possibility of making an error.

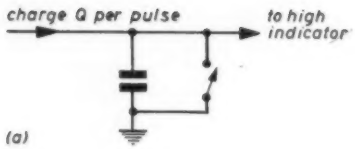
Clothing monitors

There are many special-purpose contamination monitors. They are similar, in principle, to the general-purpose contamination monitors, but designed so that some specific measurement can be made quickly and easily. An example of this class of instrument, much in demand at nuclear power installations, is the hands and clothing monitor shown in Fig. 8. Two probes, one for alpha-activity monitoring and one for beta-gamma-activity monitoring similar to those already described, (see Fig. 1 and Fig. 4) are employed, but it may be noted that it would be possible to use one combination probe in the place of the two. The combination probe would utilize the technique used in Fig. 3. In addition facilities are provided for quickly checking the presence of any radioactive contamination on the hands. For this purpose either an air-proportional counter, or a large-area scintillation counter for alpha-contamination, or a bank of geiger counters for beta-contamination measurements, is employed (*11*). Alternatively, it is possible to employ the system illustrated in Fig. 3 and monitor both alpha- and beta-contamination on the hands simultaneously. To carry out a check on the hands it is necessary to place the hands through the flaps in front of the detectors, when the hands are in position, a microswitch operates, starting a timing sequence. During this time the counters move up to the hands and a count is made for a pre-set time, usually a few seconds. Each pulse produced is used to charge a storage capacitor, and so the total charge on the capacitor at the end of the counting period is proportional to the total counts in this time, and therefore, the activity. Two storage capacitors are employed, one for each hand, and the charge collected in each case at the end of the counting period is displayed on meters on the main panel of the monitor. If the deflexion is above that corresponding to one maximum permissible level (600 deflexions/min per hand in the case of alpha-active contaminants and 6000 deflexions/

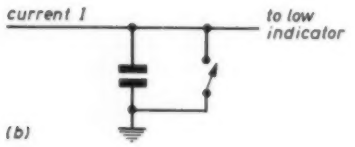


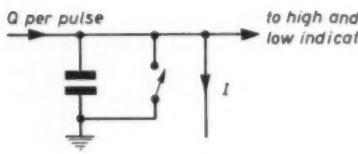
Hands and clothing monitor used in nuclear power installations (Fig. 8)

*See earlier series of articles in NUCLEAR POWER, June, July, and August 1957, by D. B. Barnes.



The basic counting circuit (a) and the basic timing circuit (b) used in the hands and clothing monitor (Fig. 9)





New circuit, proposed by Cooke-Yarborough and Barnes, for measuring weak radioactivities (Fig. 10)

min per hand in the case of beta-active contaminants) a trigger circuit is operated and an alarm signal operates. It is also usual to arrange the trigger circuit to operate if the hands are removed before the counting period is completed. This latter ensures that all operatives carry through the monitoring operation properly and there is no slackness.

Somewhat similar apparatus involving large-area scintillation counters or banks of geiger counters are employed in laundries at atomic energy establishments for checking overalls and other clothing before and after laundering. Checking before laundering is necessary in order to sort clothing according to the level and extent of the contamination, clothing which has become heavily contaminated being laundered separately. Again it is possible to use the combination type of detector for monitoring both beta- and alpha-contamination simultaneously with a corresponding saving in time.

Determination of weak radioactivities

The problems of contamination monitoring have been studied recently by Cooke-Yarborough and Barnes (*12*), who have considered particularly the problem of ascertaining whether the activity of a weak radioactive sample is above or below a pre-determined level. To understand their proposals, we must refer again to the hands and clothing monitor already described. In the equipment described (Fig. 8) the counting circuit is fed with charge pulses from the counter and these are used to charge a capacitor which, when it rises to a set voltage, operates a trigger circuit operating a 'high' alarm. Meanwhile constant current is fed to a capacitor in a timing circuit, which operates a 'low' alarm if it reaches the pre-set voltage first (Fig. 9). At the end of this period both capacitors are discharged and the sequence can be re-started again.

In the new circuit (Fig. 10), proposed by Cooke-Yarborough and Barnes, charge is fed to a capacitor from the discharge of the counter as in the previous system, but constant current (corresponding to that current which would be fed to the capacitor with a mpl on the hands) is bled from the capacitor. It is instructive to consider hands being tested with no contamination; the voltage on the capacitor will then fall and, eventually, at a pre-se negative voltage cause a 'low' indicator to operate. With heavily contaminated hands it would rise and at a pre-set positive voltage cause the 'high' indicator to operate. Hands contaminated at intermediate levels would cause the voltage to fluctuate up and down with the usual statistical variations operating either the high- or low-level indicator. The advantage of this technique is that there is a considerable saving in time in dealing with hands with low or heavy contamination, and the longer time is only required for checking contamination near the m.p.l.

Cooke-Yarborough and Barnes have shown that their new approach leads to a considerable saving in time as compared with the usual method, and according to their computations, should result in a saving in time by an overall factor of between 5 and 7 times. So far no instruments are in the market utilizing this technique, but it is fairly certain that hands and clothing monitors and perhaps other forms of health instruments will utilize this principle in the future.

Selective gamma monitoring

All the instruments described so far measure the total alpha-activity, total beta-activity or total gamma-activity. This means that in dealing with contamination monitoring with instruments of this type it is necessary to know the radio-nuclide present in the contamination in order to express the results in terms of the maximum permissible levels. When the radio-nuclides present are not known, it is necessary to assume that the total activity is due to the most hazardous of the possible radio-nuclides. For this reason there has been considerable interest of recent years in the development of contamination monitors which are specific for particular radio-nuclides.

A good example of this type of monitor is the plutonium monitor (*13, 14*), which depends on the use of a gamma-sensitive scintillation counter, followed by a pulse amplifier, pulse-amplitude analyser and a counting-rate meter, the pulse-amplitude analyser being set-up to receive the 17 keV gamma-emissions which are emitted by Pu-239. High sensitivity has been obtained with this instrument, and modified instruments have been developed* for monitoring U-235, Cs-137 and I-131 by the same selective gamma-monitoring.

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by Plessey Nucleonics Ltd.

Cross Section by GRACCHUS

I WAS pleased to hear Mr. G. R. Newbery, acting Safety Officer at the UKAEA's Radio Chemical Centre, saying at the Royal Society of Health Congress at Torquay recently that if the smallness of radiation hazards was more generally appreciated a wider use of radioisotopes would result. Apparently his views are not shared by some members of the House of Commons. During discussion on an amendment to the Radioactive Substances Bill, it was deplored that radioactive material which recently arrived in Liverpool from the United States was treated somewhat casually and that the port officer of health was 'left this nuclear baby over the whole of one weekend while the material itself was in some backyard with only a watchman on guard'. I couldn't help thinking when I read that of the piece of doggerel which goes:

> Little Charles when the guards were gone,
> Tampered with a cyclotron.
> His parents find him less attractive,
> Now that he is radioactive.

FINDING AND distributing information is not a problem confined to journalists alone. I find that though this is difficult enough at times, the problem is even more pressing for research workers. In fact, one fear expressed to me recently was that progress might slow down because of the inability to keep abreast of work done by others. Looking a bit more carefully into the matter, I realised what was meant when faced with the index to Nuclear Science Abstracts published by the US Atomic Energy Commission. Not only was the weight of it impressive—3½ lbs—but there were some 3,000 pages . . . and this for an index alone. The way some research workers overcome this, according to a recent inquiry into the reading habits of electrical and electronic technologists in Britain, is simply by asking someone else. Apparently this is the best way though another authority, the New York Botanical Gardens, still thinks that some reference volumes are necessary. It is going ahead with a mammoth plan to record names of plants, common names, original authors, place and date of publication and bibliographies in 21 volumes of 1,000 pages each. Personally I'll obtain my information by asking questions.

HIS RECENT trip to Britain as guest of the Federation of British Industries (FBI) has given Sr. Jaimie Mac-Veigh, director of the Spanish concern, Centrales Nucleares SA, a story that he re-told me with much amusement. While visiting Harwell, he was accompanied by a representative of the Federation. This gentleman, while talking to a Harwell scientist, was asked whom he represented. The reply came back: 'The FBI'. The Harwell comment was: 'You chaps certainly get around. I had no idea the G-Men were so interested in following Sr. Mac-Veigh'.

A REFRESHING resume of the business philosophy of Dow Chemical International was given by Mr. Ben Branch, the 45-year-old president, when I met him in London recently. He was completing a tour of Europe looking at Dow's expansion overseas. 'Our expansion', he said, 'should not be regarded as a challenge. After all, the chemical industry is a two-way street. But there are certain products in which we believe we have a special leadership. Our aim is to provide a service for everybody and make a bit of money for ourselves. The really beneficial enterprise is that which is complementary, that which fills an urgent need and adds to the balance and harmony of the economy'.

Dow Chemical Company is, of course, associated with the Rio Tinto group of companies in Canada and the United Kingdom and it and Rio Tinto jointly hold the share capital of Thorium Limited in the UK.

A STAINLESS steel cylinder that floated in liquid concrete instead of sinking gracefully as planned, caused one of those hitches that happen in the best organized events. It was only after some prodding with a trowel and assistance by two workmen that Dr. Sigvard Eklund, chairman of the Dragon Board of Management, was able to complete the ceremony inaugurating the start of the construction of the reactor experiment at Winfrith Heath. This had consisted of placing the cylinder containing plans of the reactor, a copy of the project agreement and coins from signatory countries, upright in a specially dug out hole in the concrete foundations. While this incident provided added time for the photographers (incidentally, when is the photographer at Winfrith Heath to be supplied with a camera by the AEA?), it also prompted the 'encouraging' remark from bystanders: 'let's hope the reactor doesn't do the same.'

I NOTICE that the US Navy has now developed long-range sonar equipment which is 18 times as powerful as that used during World War II. This may turn out to have been unnecessary if the submarines they have to track are as noisy as their own nuclear vessels. I believe that the Nautilus type, which apparently travels at about 60 miles an hour, can be heard a long way off. Main cause of the trouble is the pumps used with the pressurized water reactor: they emit a high pitched whine that any destroyer with reasonable tracking equipment can follow.

This perhaps emphasizes the choice of the direct cycle boiling water reactor (see *Woldview*, May) in the report by the US Maritime Commission which was sponsored by the US AEC. A submarine powered by this unit would be quieter and be without the expensive—nearly £9,000—pumps that are apparently at the root of the trouble.

AN ADDED hazard to having an accident while working with radioactive equipment is that one might literally be posted to hospital. A technique used in the United States some time ago when a General Electric Company employee dropped a steel table on his foot and fell against a 'hot' piece of equipment was to decontaminate him and send him to hospital in a cellophane envelope to 'keep him from spreading radiation through the wards'. When he arrived at the hospital he was treated for four broken toes!

On Record

The prices for the first atomic stations were too low—we hope later tenders will be sensible and permit a reasonable profit.

F. Taylor, chairman, Taylor Woodrow Limited.

Cleaning heat exchanger elements

Ultrasonics clears contamination

The life of reactor fuel element cans depends very much on the absence of contamination, the presence of which accelerates high-temperature corrosion. The problem, serious enough in the case of aluminium and magnesium alloy cans, is even more critical with the beryllium alloys which are expected to come into service in the next generation of reactors in this country, and which will be used in the Atomic Energy Authority's experimental Advanced Gas-Cooled Reactor being built at Windscale. At the higher temperatures and efficiencies which these new materials will make possible, beryllium is extremely reactive and great care must be taken to exclude from the primary gas circuit every trace of dirt, both during manufacture and in operation.

By their size and complexity of construction, the heat exchangers are at the same time the most likely source of foreign matter, and the most difficult components in which to ensure really thorough cleanness. In the manufacture of the elements for the AGR, International Combustion Ltd. are employing, on a large scale, cleaning methods which have hitherto been associated more with laboratory and instrument techniques than with heavy engineering.

Evaporator sections measure about 16 ft by 6 ft, the elements of which are of 2 in. diameter rimming steel tube, with spiral gills of 18-gauge silicon-killed steel, pitched six to the inch and half an inch deep. The removal of all traces of debris, surface corrosion, scale and welding residue from the narrow and deep spaces between the gills is difficult, yet nothing less than perfection is acceptable. The initial cleaning procedure, consisting of successive citric acid pickles and rinses, removes the bulk of the scale and coarse soil.

Ultrasonic cleaning

Although this treatment, followed by perhaps conventional degreasing, would suffice for normal heat exchanger applications, it was considered by the AEA that special measures were necessary to ensure complete penetration of the cleaning actions to the roots of the fins, and to ensure that loosened soil was not re-deposited on cleaned surfaces. Accumulating proof of the effectiveness of ultrasonic cleaning of small intricately shaped articles resulted in the decision to specify ultrasonic treatment for these large components. Nothing on this scale had been tackled before, and a special installation had to be designed and installed.

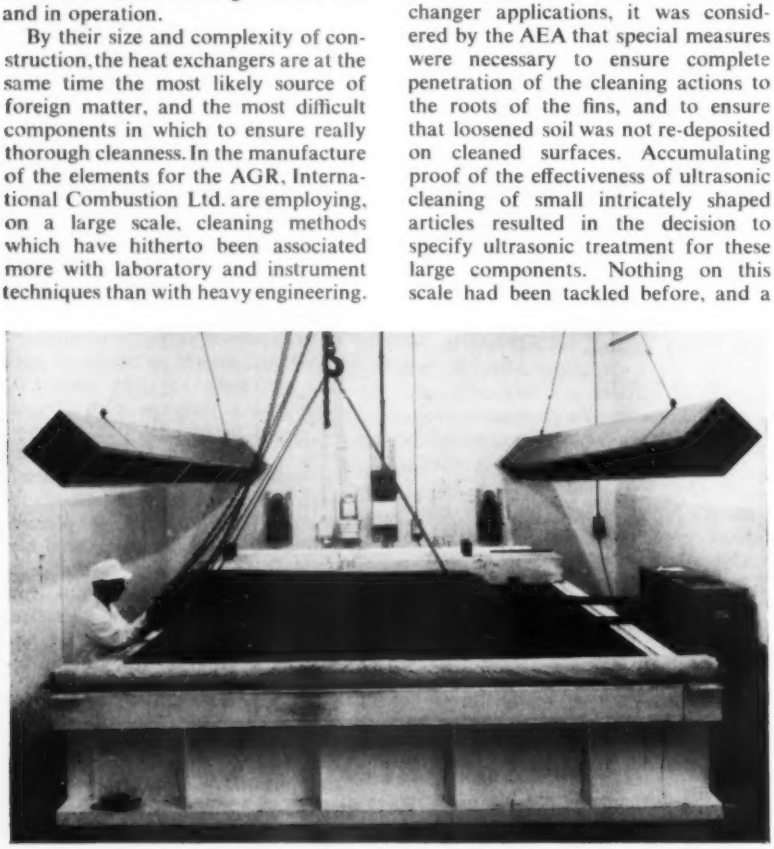


Fig. 1 Heat exchanger elements immersed in trichlorethylene are subjected to intense ultrasonic energy from the generators at the right

Fig. 2 Two Dawe 4 kW Soniclean generators energize the transducers at 40 kc/s. A simple tuning control is adjusted to obtain maximum output

A 'clean room' was built, with a filtered and pressurized atmosphere, in which the rectangular steel tank illustrated in Fig. 1 was erected. Measuring 17½ ft by 10 ft, and containing 1500 gallons of trichlorethylene, it is large enough to take the biggest elements required. Ultrasonic energy is supplied by fourteen immersible transducers mounted diagonally in a box mounted on runners, thus forming a trolley which can be traversed over the entire length of the tank.

To concentrate the ultrasonic energy as much as possible, the heat exchanger elements are segregated into groups of two pipes each by mild steel baffle plates. The transducer carriage is arranged to traverse the length of the tank in steps, so that only one group of elements is treated at a time. Any airborne dust which might be admitted despite the precautions taken is excluded by a roller blind screen (half of which is visible in the foreground of Fig. 1), which covers the top of the tank on both sides of the transducer carriage. Exhaust ducting above the tank removes fumes, although the rate of air supply to the room is sufficiently high to maintain positive pressure.

Energizing the transducers

The transducers are energized by the two Type 1153 Dawe 'Soniclean' generators shown in Fig. 2, each unit having a peak output of 4 kW at about 40 kc/s pulsed at mains fre-

quency. Operation is simple and the only adjustment required is to turn the tuning control on the right of each generator until a peak output reading indicates optimum matching to the job.

The frequency of 40 kc/s has been chosen by experience, because it offers good penetration of crevices and interstices and a vigorous cleaning action, without the masking effect suffered by higher frequencies, which have marked directional properties. The actual cleaning action is due to cavitation, in the form of millions of minute vapour bubbles which alternately form and collapse violently at the liquid-solid interface as the liquid is subjected to waves of tension and compression, transmitted to it by the transducers.

Each group of two pipes is exposed to ultrasonic radiation for five minutes, which is sufficient to remove the most tenacious soil, and removed debris is held in suspension by the continuous agitation, so that it cannot settle again on the cleaned surfaces.

Heat exchangers cleaned in this way have been found to be free from all traces of foreign matter. To retain this state up to assembly in the heat exchanger vessels, the cleaned elements are never exposed to the outside atmosphere, nor to normal shop conditions.

Aluminium based material for shielding

Improved properties with boron carbide

A specialized technique has been developed by High Duty Alloys for the production of new thermal neutron shielding materials with vastly improved formability, to be known as the Hiduminium 400 series. The product consists of boron carbide (B_4C) of suitably fine mesh size, evenly dispersed in a fully wrought aluminium matrix, clad on both sides with high purity aluminium. This material differs radically from conventional Boral which is produced by a powder metallurgy technique and is non-formable; it is also substantially cheaper.

A method has been perfected by which the B_4C particles can be uniformly suspended throughout molten aluminium, followed by semi-continuous casting to a rolling slab which is then clad and rolled in the normal manner. The B_4C used has a purity better than 99% and the concentration in the new material can be adjusted to suit customers' requirements, the maximum addition being 30% B_4C by weight. Particle size can also be varied between 80 and 200 mesh but for maximum formability the coarser mesh sizes are preferred. The cladding, which is used primarily to protect the roll surfaces during fabrication, can be varied from a minimum of 5% each side compared with conventional Boral; therefore, a much greater effective core thickness may be obtained. The plate or sheet is normally supplied in standard sizes either 72 in. or 96 in. long × 36 in. or 45 in. wide, over a wide range of gauges. Lengths greater than these can be produced, however, for special applications, for example, at a total thickness of 0·180 in., a plate 180 in. × 45 in. can be supplied.

The new materials have light weight, good corrosion resistance, good heat conductivity, stability up to the melting point of aluminium and the ability to absorb thermal neutrons without the production of hard gamma radiation.

Properties of Hiduminium 400

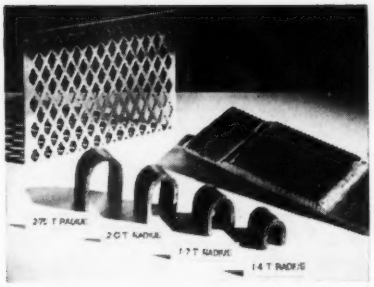
The increase in formability over conventional Boral is most marked; sheet $\frac{1}{4}$ in. thick containing 15% and 30% boron carbide can easily be bent cold round radii of 3T and 6T, respectively. Tubes and cylinders can be manufactured by bending the annealed sheet and seam welding the butted joint.

Typical thermal conductivity values for 15% B_4C material are approximately 320 B.t.u./ft²/h for 1 in. thickness and 1°F temperature difference.

Typical Mechanical Properties

DESIGNATION	B_4C %	CONDITION	THICKNESS	U.T.D. tons/in²	% ELONGATION
	20	Annealed	0·25 in.	4·2	11
Hiduminium 420	20	Annealed	0·064 in.	3·3	4
	20	Annealed	0·025 in.	2·9	3
Hiduminium 415	15	Annealed	0·175 in.	5·2	7

The last two figures in the Hiduminium nomenclature denotes normal percentage boron carbide content.



Examples of welding, forming and punching illustrate the improved formability on Hiduminium alloys. $\frac{1}{4}$ in. sheet can be bent cold round 3T and 6T radii

Design suggestions

Drilling, which is only recommended when holes cannot be reached with a punch, is performed by carbide tip drills at slow speed and high feed pressure. The punch is also carbide tipped and both the punch and the die, which is of hardened tool steel, must be kept sharp to maintain hole sizes. The material can be sheared but shear blades must be kept sharp to ensure maintaining the tolerance.

If the argon tungsten arc method of welding is used, no serious problems are encountered during the welding of plate to plate etc., and commercially pure aluminium (GIC) and 5% silicon-aluminium (NS.21) filler rods can be used with equal success. Where two plates are to be welded together a strap type weld is recommended.

Crystalline fuel

US development

A process for preparing fuel materials which results in a crystalline rather than a ceramic product is now fully developed by the US Spencer Chemical Company. The materials are: uranium dioxide, thorium dioxide, urania-thoria in solid solution, triuranium octoxide, uranium monocarbide and uranium dicarbide. Fuel elements can be prepared simply by vibrationally compacting the crystalline product inside the fuel rod. The crystalline fuels may also be swaged (a rotary compacting process), as well as vibrating into a compact rod.

The General Manager, Harold Lambertus, said recently that fuel loss during vibration is 0·25% compared with a 1% loss with standard ceramic materials. The power efficiency of the fuel elements is increased because fuel tube density is increased from 88–89% to 91–92% of theoretical density. Reprocess scrap is also reduced from 15–20% to less than 5%.

A 6000 lb lot of arc-fused uranium dioxide was recently approved by the USAEC Hanford Works.

A mechanism of graphite lubrication which reconciles the structural and sorption theories

Colloidal graphite lubrication

by E. R. BRAITHWAITE, M.Sc., F.Ph.S., F.R.I.C.,
Research and Development Manager, Acheson Colloids Ltd.

MANY THEORIES have been advanced on the lubricating mechanism of graphite; they can be divided into two main groups which have hitherto been considered mutually irreconcilable.

First there is the original structural theory arising from the discovery by Bragg (*1*) who showed that the relatively large distances between the layer planes are sources of weakness in the mutual attraction between these planes and, in turn, give rise to the interplanar mechanical weakness or 'slip action' associated with graphite. This is not in agreement with practical experience where it is found that colloidal graphite is beneficial in such a system, and is presumably due to the fact that a cast or machined cast iron surface whilst containing the ingredients of a 'run in' surface does not have a good topography. The presence of additional graphite during 'running in' thus protects the metal/graphite surface from unnecessary breakdown and the ultimate bearing surface benefits more fully from the graphite indigenous to the cast iron. Later Jenkins and Holm (*2*) showed by electron diffraction that graphite crystals are oriented along the main Bragg cleavage planes when rubbed. The theories in this group are based on the assumption that the lubricity of graphite is due in the main to the anistropic structure of graphite.

Secondly there is what might be termed the sorption theory which really arose out of Holm's suggestion that the occasional wear of graphite surfaces is due to the tilting of the crystals so that their edges are able to abrade adjacent surfaces and the abrasion could be minimized by the presence of water vapour. This was developed by Savage (*3*),(*4*) who later stated that the slipperiness of graphite is not inherent in the crystal structure alone but depends upon adsorbed films, especially water, which cover the carbon atoms and provide surfaces of low cohesion; the salient features of this hypothesis have been reviewed by the author (*5*). The purpose of this paper is to suggest a mechanism which will reconcile the sorption and structural theories. The evidence is not limited to specific laboratory techniques but also takes into account the vast amount of data available from the engineering industry in which solid lubricants are so widely and successfully used.

Consider two rubbing surfaces of similar or dissimilar metals separated before sliding by an abundant supply of graphite either dispersed in a liquid or in the dry film form; such a system is represented in Fig. 1.

The 'bits' of graphite *G* are randomly orientated as would be expected in the dispersed form. Let the two surfaces move under load so that there is a force *L* normal to the rubbing surfaces and a shear force *S* parallel to the direction of movement as represented in Fig. 2.

The main effect on the system of this movement under load is to bring the bearing surfaces closer together and orientate the 'bits' of graphite with their major axis parallel to the direction of sliding. Simultaneously there is mechanical interaction between the surface asperities, and the grinding action of these on the 'bits' of graphite trapped between them; these 'bits' of graphite prevent the welding of the asperities and reduce wear by their bulk parting action. The time during which this grinding takes place is the period of maximum deformation in the running life of these two surfaces. In the absence of a suitable lubricant the deformation and welding of the asperities leads to the formation of metal debris and the rate of wear is high—so high in fact that the generated heat welds relatively large areas of two surfaces together and 'seizure' ultimately occurs. In the presence of graphite, however, plastic flow occurs at the asperities and the surfaces gradually 'mate' together with a minimum of wear. We have referred to 'bits' of graphite to distinguish them from discrete graphite particles; they are in fact aggregates of crystallites (Fig. 3) and these break down on grinding to two types of particle *A* and *B* (Fig. 3) due to the fact that small pieces are broken off which then reaggregate at points where the surface energy is highest (or where new surfaces are exposed).

This period of maximum deformation of the sliding surfaces and breaking up of graphite 'bits' into more orientated groups of crystallites is important for they are able to chisel their way into the deforming plastic metal surfaces (Fig. 4) and form a sort of 'Beilby' layer. It is therefore apparent that the pressure at which the metal begins to flow under stress is important. Goodman and Deacon (*6*) quote the interesting case of talc (hardness = 2–3 Mohs) which will protect gold but not platinum (hardness = 4·3 Mohs) and suggest that this may be due to the fact that talc can penetrate the softer metal but not the harder one.

Fig. 1 Two rubbing surfaces separated by dispersed 'bits' of graphite

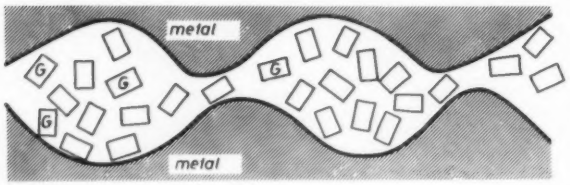
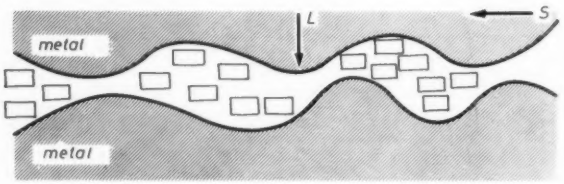


Fig. 2 Surfaces moving under the action of normal and shear forces



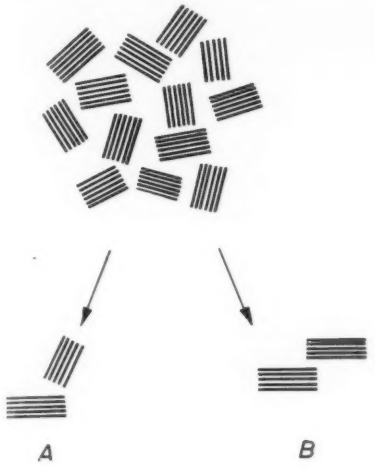


Fig. 3 Breakdown of the graphite 'bits' into two types of particle A and B

The 'Beilby' layer is made up of metal, metal oxide and graphite crystallites with their major axis lying parallel to the surface. The orientated graphite crystallites thus embedded into the newly formed metal surface, Fig. 5, can now function as 'built-in lubricants' by themselves shearing along their basal cleavage planes, thus reducing the overall rate of wear.

Since graphite has such a low modulus compared with the surrounding metal matrix, the embedded graphite can be regarded as holes and H/E for the composite surface will be greater than H/E for the pure metal (ferrous) surface and hence the rate of wear (abrasive type) will be less. In theory therefore the excess solid lubricant present between 'run-in' sliding surfaces will be utilized only in an emergency. Angus (*7*) has observed that the addition of graphite to a new cast-iron surface appears to have little advantage, since sufficient graphite is already present to cover the running-in period. This is too simple a picture however, for the planes are held together by strong molecular forces and it is more likely that the key to this movement lies in the presence of dislocations or areas of atomic disorder which weaken the binding forces. The existence of such disorders was first proposed by Frank (*8*) who proposed a new mechanism for crystal growth based on the fact that graphite crystals can only grow in the presence of dislocations which have a screw component ending on the external planar faces of graphite. It was concluded that fully developed graphite crystals must contain dislocations within the lattice. The presence of several types of dislocations in graphite have since been demonstrated by Tsuzuku (*9*) who suggests that the main cause of such lattice disorders during the formation of graphite is probably the very high thermal stresses caused by the anistropic expansion of the crystals at the graphitizing temperature.

The author considers that the most important factor during this running-in period is the type, shape and size of the dispersed graphite particles. If, for example, the graphite has been size-reduced in air before dispersion then the disorientation factor will be high. This has been shown by Bacon (*10*) who has shown the progressive reduction in crystallinity of graphite by grinding. This damage to the lattice cannot be restored even after annealing at 1500°C and is due to the transformation of normal graphite to a turbostratic or rhombohedral structure. Confirmation was obtained in a different way by Hickman (*11*)

Fig. 4 Breakdown of the graphite 'bits' into orientated groups of crystallites during the period of maximum deformation

who compared the oxygen contents of milled samples of graphite with their surface area. It was found that the crystallites of the unmilled graphite have a shape factor of 12 (i.e. the edge length of the crystals is twelve times the thickness, the lattice planes being parallel to the large faces). During milling, the crystallites become increasingly isotropic, until a shape factor of approximately 1·5 is attained. The author (*12*) has found that the isotropism (or the isotropic state) produced by ball milling is irreversible in so far as mechanical or chemical action is concerned and therefore it follows that the 'type of graphite' in colloidal suspension is very important. The size of the dispersed graphite particles is also important in commercially available graphite dispersions, for whilst the 'running-in' of metal surfaces is easier with fine graphite, there is a limit to effective fineness due to the superimposed effect of aggregation. It is considered from experience, that an optimum average particle size is about 1–2 μ, provided the degree of sub-division has been achieved without undue disorientation of the crystallite aggregates and distortion of the crystallite lattice. Whilst it is outside the scope of this paper, it should be mentioned that most commercially available dispersions of colloidal graphite contain additives which if carefully chosen can enhance the running-in of surfaces by the cushioning effect they impart to the graphite 'bits' while they are being sheared.

It has been suggested that colloidal graphite is removed from metal surfaces which are sliding over one another in the presence of a detergent oil due to the fact that the graphite particles are desorbed. This assumes that the graphite particles are physically adsorbed to the metal surface, which is contrary to the ideas already put forward in this paper. Goodman (*13*) has demonstrated qualitatively by electron diffraction measurements that there is no difference in the behaviour of graphite whether it is in the presence of a straight paraffinic oil or a fully detergent oil. It is suggested that such a mechanism of graphite lubrication is, for all practical purposes, completely independent of surface chemical criteria except in so far as the presence or absence of surface films on the graphite will influence the mode of breakdown of the 'bits' but such differences will not be large enough to influence the rate of wear.

It has been shown by Goodman and Deacon (*6*) that the lubrication action of graphite in air at temperatures above about 450°C is impaired due to oxidation. These conclusions cannot be taken too literally for there are many examples in industry (e.g. fine wire drawing (*14*)) where colloidal graphite continues to function satisfactorily as a lubricant at temperatures far in excess of the temperature at which graphite begins to oxidize under laboratory conditions.

There are two major differences between the author's theory and the Savage theory.

1. We have postulated the formation of orientated groups of crystallites, whilst the sorption hypothesis considers only 'bits' of graphite—or disorientated aggregates of crystallites.

2. We have discussed the behaviour of *two* metal surfaces moving under load in the presence of an abundant supply of graphite, whilst Savage considers only a block of graphite moving relative to *one* metal surface.

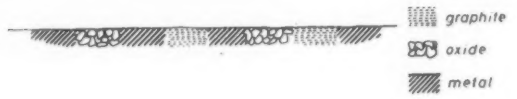


Fig. 5 Orientated graphite crystallites embedded in the metal surface acting as 'built-in lubricants'

First the graphite rods or brushes; these are formed by some mechanical process which gives to the block a degree of orientation that will be higher for extruded blocks than for compressed blocks. Thus the interaction between the block of graphite and the moving metal surface will depend primarily on the orientation of the block. This was demonstrated by Campbell and Kozak (*15*) who found that a highly orientated graphite brush, operated so that the faces of the cleavage planes rub on a plane rotating copper surface, neither dusts nor produces wear on the copper surface in dry nitrogen. When, however, it is operated so that the edges of the cleavage planes rub against the plate, rapid dusting wear occurs and the copper surface is deeply scored.

Considering the second point of difference it can be seen that the presence of adsorbed films would be important in systems of the type used by Savage. Not only would they influence the breakdown of the blocks but they would also protect the single metal surface from being scored by the hard crystallite edges of the aggregates worn off the graphite block by the copper. It is also readily seen that only gases condensible at room temperature (as postulated by Savage) would afford such protection, for the non-condensible gases would not be adsorbed sufficiently strongly to the metal or graphite surfaces to give a cushioning effect. Similarly, the effect of outgassing at elevated temperatures would be to remove all means of protection against wear by the hard graphite edges from the copper surface. The importance of having two sliding metal surfaces under load will also be appreciated for they encourage the solid lubricant to remain between the rubbing surfaces rather than be removed as debris.

Conclusion

Colloidal graphite functions as a solid lubricant between two sliding metal surfaces because of its anistropic characteristics and the effectiveness of colloidal graphite as a solid lubricant depends on its state of subdivision and degree of orientation of the aggregates of crystallites. It is independent of the presence of adsorbed films. The main criterion for efficient lubrication by colloidal graphite is that the metal surfaces should be properly 'run-in' with graphite.

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A summary of a mathematical basis for harmonic-perturbation analysis of the radial spatial behaviour of a controlled reactor

Reactor radial spatial behaviour

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SPATIAL ANALYSIS of large reactor behaviour has focused attention on the regional distortions which can occur to the steady-state flux distribution in some conditions (*1–4*). The reactor control system must be able to detect and control the effects of these local disturbances in addition to the more familiar functions of overall control of the core.

In analysis the radial/azimuthal and axial spatial effects can often be considered separately. This article summarizes a mathematical basis for harmonic-perturbation analysis of the radial spatial behaviour of a controlled reactor, suitable, for instance, for the study of the short-term transient behaviour of a core with graphite-sleeved fuel elements. Any radial distribution of control rods can be considered, each controlled by locally averaged outlet gas temperature changes. Disturbances in absorber can be introduced at any point in the reactor, and the resultant behaviour studied. The approach was originated in The Development and Engineering Group of the UKAEA, and has been extended to permit detailed study of actual designs. The equations can be extended further to include long-term effects, including xenon-poisoning changes, without difficulty.

The one-group neutron-diffusion equation for a small region of unit dimensions anywhere in the core of a homogeneous unreflected reactor is considered. Neglecting xenon and bulk-moderator temperature changes, averaging the quantities over the core axial length with statistical weighting of reactivity terms, and linearizing the variables for small perturbations, the equation becomes

$$\tau \frac{\partial H}{\partial t} = M^2(\nabla^2 + k_0^2)H + H^*(\rho_C + \alpha_S T_S - \alpha_U T_U) \quad (1)$$

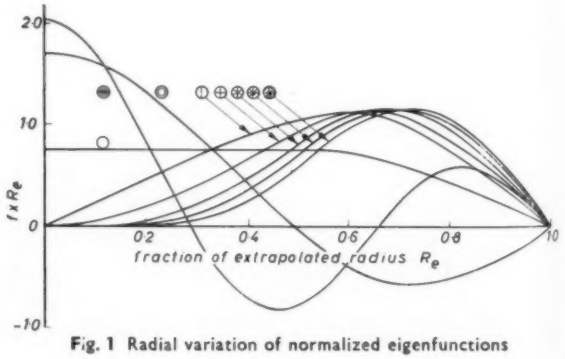

Fig. 1 Radial variation of normalized eigenfunctions

where the asterisk indicates the steady state value, H is local/core-average heat-production ratio, ρ_C represents control and disturbance reactivity, T_U and T_S are fuel and sleeve local temperatures, α_U and α_S are fuel and sleeve temperature coefficients of reactivity, τ is neutron effective mean lifetime, M^2 is neutron migration area, and k_0^2 is a quantity involving the steady-state hot poisoned reactivity and the axial core neutron leakage, averaged over the core axial length.

The movement of a control rod at any point results in the addition of a cylindrical element of absorber at the rod tip, and this is regarded as producing a change of k_∞ in a small volume near this point, not necessarily the same as the absorber volume added. The effect is considered negligible at other points.

Axially statistically weighted temperatures suitable for use in the reactivity terms of equation (1) are available from the heat-transfer equations given in (5). Ignoring radiation terms and terms associated with very long or very short time constants, and with constant gas flow and inlet gas temperature, the equations of ref. (5) apply to perturbations about steady state values, and become:

$$C_U \frac{\partial T_U}{\partial t} = G_U H - P_1\left(T_U - \frac{T_C}{2}\right) \qquad (2)$$

$$C_S \frac{\partial T_S}{\partial t} = G_S H - P_2\left(T_S - \frac{T_C}{2}\right) \qquad (3)$$

$$T_C = \mu T_U - \nu T_S \qquad (4)$$

where C_U and C_S are specific thermal capacities, G_U and G_S indicate proportions of heat production in fuel and sleeve respectively, P_1, P_2, μ and ν are heat-transfer constants, and T_C is outlet gas temperature.

The variables in equations (1)–(4) are radial space and time dependent. It is assumed that each variable can be expanded in an infinite series of space and associated time functions. The space functions chosen are the set of orthonormal eigenfunctions $f_i(r,\theta)$ defined as solutions of the equation:

$$(\nabla^2 + B_i^2)f_i = 0, \qquad (5)$$

satisfying continuity and boundary conditions through the core. B_i^2 can vary through the core, but if the difference $B_i^2 - B_0^2$ is constant, then the functions f_i form a complete orthogonal set and can describe any function. Choosing B_0^2 equal to the material buckling in each zone makes f_0 proportional to the steady-state flux. In particular, for a cylindrical reactor with two radial zones bounded by outer radii R_1 and R_2, f_i is given for the inner and outer regions respectively by:

$$C\begin{pmatrix}\sin i\theta\\ \cos i\theta\end{pmatrix}\frac{J_i(\beta_{1i}r)}{J_i(\beta_{1i}R_1)} \quad \text{and}$$

$$C\begin{pmatrix}\sin i\theta\\ \cos i\theta\end{pmatrix}\frac{J_i(\beta_{2i}r)Y_i(\beta_{2i}R_2) - Y_i(\beta_{2i}r)J_i(\beta_{2i}R_2)}{J_i(\beta_{2i}R_1)Y_i(\beta_{2i}R_2) - Y_i(\beta_{2i}R_1)J_i(\beta_{2i}R_2)},$$

where C is a normalizing constant. The orthogonality condition is then given by:

$$\int_A f_i f_j \, da = \delta_j{}^i \qquad (6)$$

where A is the core cross-sectional area, $\delta_j{}^i$ is the Kronecker delta (o, $i \neq j$, and 1, $i = j$), and β_{1i}, β_{2i} satisfy:

$$\beta_{2i}{}^2 - \beta_{2o}{}^2 = \beta_{1i}{}^2 - \beta_{1o}{}^2, \qquad (7)$$

and

$$\beta_{2i}\frac{J_{i-1}(\beta_{1i}R_1)}{J_i(\beta_{1i}R_1)} = \beta_{2i}\frac{J_{i-1}(\beta_{2i}R_1)Y_i(\beta_{2i}R_2) - Y_{i-1}(\beta_{2i}R_1)J_i(\beta_{2i}R_2)}{J_i(\beta_{2i}R_1)Y_i(\beta_{2i}R_2) - Y_i(\beta_{2i}R_1)J_i(\beta_{2i}R_2)}, \qquad (8)$$

neglecting any difference between the diffusion coefficients in the two zones. For a flattened reactor, $\beta_{1o} = 0$ and β_{2o} is the smallest solution of:

$$J_0(\beta_{2o}R_2)Y_1(\beta_{2o}R_1) = J_1(\beta_{2o}R_1)Y_0(\beta_{2o}R_2) \qquad (9)$$

The radial variations of the first few eigenfunctions f_i for a flattened cylindrical reactor are shown in Fig. 1.

Put $H = \sum_i f_i H_i$, where the $f_i = f(r,\theta)$ satisfy equation (5). H_i is a function of time only, and the sums are to infinity unless otherwise defined. Note that in equation (1) $H^* = f_0 E$ with E constant.

The corresponding temperature expansion is divided by f_0 so that the fundamental condition gives constant temperature across the reactor. This implies that $P_1 = p_{1o}f_0$ and $P_2 = p_{2o}f_0$ in equations (2) and (3), with p_{1o} and p_{2o} constant. Put:

$$T_U = \frac{1}{f_0}\sum_i f_i U_i\,, \quad T_S = \frac{1}{f_0}\sum_i f_i S_i\,, \quad T_C = \frac{1}{f_0}\sum_i f_i C_i\,.$$

Having expanded the variables, the orthogonality condition can be used to isolate the individual harmonic time dependences by multiplying by f_j and integrating over the core using equation (6). ρ_C is zero except over a small area δa near a point q of absorber change, and f_j and f_0 can be given average values $(f_i)_q$ and $(f_0)_q$ in this area, so that:

$$E\rho_C\int_A f_j f_0 \, da = E\rho_C(f_j f_0)_q \delta a = ER_{jq}, \text{ defining } R_{jq}\,.$$

Consideration of the neutron kinetic equations for different harmonics shows that if R_{oq} is the reactivity change due to absorber movement at q for the fundamental, then for higher harmonics:

$$R_{jq} = R_{oq}\gamma_{jq}\,, \text{ where } \gamma_{jq} = \left(\frac{f_j}{f_0}\right)_q\,.$$

R_{oq} is known for rods from detailed control-rod theory. For simultaneous rod or absorber movements at different parts of the core, the total reactivity effect on a harmonic is:

$$R_j = \sum_r R_{jq}\,, \text{ summed over } r.$$

Put $H_j = EF_j$, $D_U = EG_U$, $D_S = EG_S$. Then, using equation (5), equations (1)–(4) give:

$$\tau\frac{dF_j}{dt} = M^2(k_o{}^2 - k_j{}^2)F_j + R_j + \alpha_S S_j - \alpha_0 U_j\,, \qquad (10)$$

$$V_j C_U \frac{dU_j}{dt} = D_U F_j - p_{1o}\left(U_j - \frac{C_j}{2}\right) \qquad (11)$$

$$V_j C_S \frac{dS_j}{dt} = D_S F_j - p_{2o}\left(S_j - \frac{C_j}{2}\right), \qquad (12)$$

$$C_j = \mu U_j + \nu S_j\,, \qquad (13)$$

where the approximation $\int_A \frac{f_i f_j}{f_0} da = V_j \delta_j{}^i$ is assumed, with V_j constant.

Equations (10)–(13) describe the time-variant parts of the perturbation components for any chosen harmonic. For instance $(H_j f_j)$ is the contribution of the jth harmonic to H at any point and time.

It is convenient to consider regional averages of the variables over the areas in which the gas outlet temperatures used for control are averaged. Let H_{j1} be the average over the local area A_1 of the jth harmonic component of

Perturbation of local power per unit lateral area

Steady-state local power per unit lateral area

Then $H_{j1} = \frac{1}{A_1}\int_{A_1} \frac{H_j f_1}{H^*}\,da = F_j\beta_{j1}$,

where $\beta_{j1} = \frac{1}{A_1}\int_{A_1} \frac{f_j}{f_0}\,da$.

The contribution of the jth harmonic to a temperature perturbation such as T_c is $\left(\frac{f_j}{f_0}\right) C_j$, and the regional average of this quantity over A_1 is:

$$T_{cj1} = \frac{C_j}{A_1}\int_{A_1} \frac{f_j}{f_0}\,da = C_j\beta_{j1}.$$

Summing for n effective harmonics, the actual area average perturbations are:

$$H_1 = \sum_n F_j\beta_{j1}, \quad T_{c1} = \sum_n C_j\beta_{j1},$$

and similarly for the other temperatures.

Sets of values of V, β, and γ can be found from the eigenfunctions, and for n harmonic components the simultaneous transient solution of n sets of equations (10)–(13) enables the spatial behaviour following any disturbance to be studied. Any control-rod movement in response to changes in local average gas temperature is given by the solution of additional equations representing the thermocouple signal lag, signal phase advance, and mechanism response effects. Figure 2 is a block diagram showing the coupling of the system, which has been used successfully for analogue and digital computation involving up to twelve harmonic components and nine controllers. Only the first few harmonics contribute significantly to the excursions.

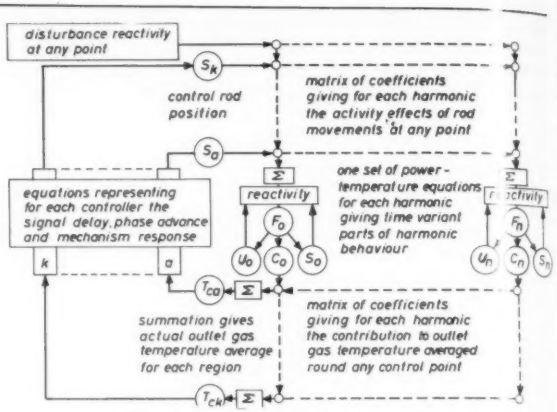
disturbance reactivity at any point
control rod position
matrix of coefficients giving for each harmonic the activity effects of rod movements at any point
equations representing for each controller the signal delay, phase advance and mechanism response
reactivity
one set of power - temperature equations for each harmonic giving time variant parts of harmonic behaviour
summation gives actual outlet gas temperature average for each region
matrix of coefficients giving for each harmonic the contribution to outlet gas temperature averaged round any control point

Fig. 2 Block diagram for the analysis

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Research on uranium–carbon alloys carried out recently in France is described

Uranium carbide—production and properties

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THESE INVESTIGATIONS have been concerned with the possible means of preparation and the physical and chemical properties of uranium carbides and more generally uranium-carbon alloys.

The methods of preparation used were:

Reaction of gaseous hydrocarbon with uranium.

Reaction of graphite with uranium dioxide

Reaction of gaseous hydrocarbon with uranium.

The first and second methods can utilize either sintering or melting. It was expected that the chemical reaction could aid sintering and thus avoid the need for the high working temperatures required for conventional UC sintering methods.

Reaction of uranium with graphite

It has been shown that a cold pressed mixture of the powders corresponding to UC react completely at a temperature of 900–1000°C (1652–1832°F) under vacuum. But the density of the product does not reach more than 80% of the theoretical (*1*).

The reaction has also been performed by hot pressing under uniaxial pressure. Under these conditions, the reaction starts as low as 450°C (842°F) and a treatment of 4 hours at 1000°C (1832°F) at a pressure of 200 kg/cm² (1·27 tons/in²) leads to a product reaching 98% of the theoretical density for a mixture corresponding to a nearly stoichiometric UC. Study of this process has shown that the very high density achieved is due to the plastic deformation of uranium before reaction.

The hot extrusion of mixtures of uranium and graphite powders has also been investigated showing a very fast rate of reaction but without a good density.

The purely thermal sintering of mixtures of uranium and graphite powders has proved it feasible to obtain large size bodies with a density ranging from 7 g/cm³ to 13 g/cm³ according to the rate of heating and the purity of the reactants.

Mixtures of uranium and graphite powders have also been treated by pre-sintering yielding a reacted product with a poor density and then densified by arc melting.

Reaction of uranium with a gaseous hydrocarbon

This method was specially investigated for the preparation of UC spherical powder from spherical uranium powder (*2*).

At 900°C (1652°F), UC and UC_2 form by the diffusion of pyrolytic carbon deposited on the surface of the particle.

To obtain UC as the only phase, it is necessary, first to react the proper amount of hydrocarbon, and second to homogenize by heat treatment to get rid of residual UC_2 and U.

Reduction of uranium dioxide by carbon

This reaction can be conducted between solid reactants.

The reaction is fast at temperatures higher than 1700°C (3092°F). The product is then a clinker with a density as low as 8–10 g/cm³.

A subsequent heat treatment does not increase the density significantly. For high densities, it seems to be necessary to melt the product.

A high-density product has been prepared by direct melting of a mixture of UO_2 and graphite in an arc furnace.

Properties of uranium–carbon alloys

We have studied these properties on stoichiometric or nearly stoichiometric UC.

The product obtained by sintering does not show evidence of dicarbide even when the composition would allow its formation. The grain size is usually small. When melting, it seems difficult to avoid the formation of some UC_2.

The thermal conductivity has been found to be 0·04–0·06 cal/s cm °C.

The thermal grain growth of these products has been studied and shows the non-equilibrium state of the low temperature sinters. Yet, it has been established that the uranium–carbon alloys produced by thermal evolution do not undergo any sizable dimensional change.

Finally, the reaction of UC with different materials has been or is being studied. Reaction with zirconium results in the decomposition of UC with formation of UZr and free uranium. Study of the reaction with graphite, beryllium, etc., is taking place.

Production of UC

The requirements of uranium carbide are that it should have high density, if possible better than 95% of theoretical; good control of the composition and the nature of the phases formed; good physical and chemical stability; low cost.

Two different methods of production were likely to be able to meet these requirements:

(a) melting and casting,

(b) sintering.

The first method was discarded because of the difficult problem of composition control involved since the melting had to be made either in a graphite crucible, using high frequency heating, or with a graphite electrode in the case of arc melting. In both cases, pickup of carbon was to be expected and seemed to make melting a less attractive method than sintering.

Sintering could be carried out using UC powder prepared beforehand and compacted. This procedure was not adopted because of the high temperatures needed and the rather poor densities achieved as has been mentioned.

It was finally decided to sinter a mixture of uranium and carbon powders since preliminary studies had shown that good results can be achieved with this method.

The first step was to build a plant to produce uranium powder.

To reduce handling costs and for operational safety, it was thought best to produce a non-pyrophoric uranium powder. This requirement made the calcium reduction of uranium dioxide practically the only possible one.

A pilot plant (*3*) was developed at Saclay. In the first stage, reduction was carried out in a pressure vessel, the 'cake' of CaO containing the uranium powder was then crushed and treated in acetic acid under such conditions that CaO and residual calcium were dissolved while uranium remained undissolved. The powder was then very fine with a particle size ranging from 5–20 μ. In order to have a non-pyrophoric powder, it was necessary to 'protect' it. The protection treatment (*4*) consisted in leaving the powder in a solution of zinc or nickel sulphate for about 1 h. The powder was then washed and dried.

In a second stage, a continuous furnace for the reaction of calcium with uranium dioxide was developed with a production capacity of 100 kg/day (220 lb/day) (*5*).

Uranium powder is now made by the Société d'Electrométallurgie du Planet à la Roche de Rame near Briançon.

For sintering, two methods were adopted:

(a) hot pressing (*6*),

(b) purely thermal sintering (*7*).

The hot pressing is carried out in a graphite die, using the 'floating die' device. The punches are made of graphite and the die itself is in a molybdenum cylinder, the role of which is to withstand the lateral pressure. The furnace is electrically heated and the pressing is made under high vacuum.

The die is filled with a mixture of uranium and graphite powder. The mixing and the quality of the graphite are two important factors which should be closely controlled.

The method yields pellets up to 30 mm (1·18 in.) in diameter and 60 mm (2·36 in.) long. The important point about this method is that a density of more than 98% of theoretical is achieved using a working temperature of 1000°C (1832°F).

This advantage of low working temperature and high density largely balances the drawbacks of hot pressing, namely, slow rate of production.

Nevertheless as used at present the method is unable to yield rods or slugs. For producing these shapes, we use thermal sintering i.e. sintering without any previous compaction of the powders.

A very homogeneous mixture of uranium and graphite powders is made using a cubic mixer. This powder is placed in a graphite die, the die is closed and brought to a Balzers high frequency furnace where six dies are placed. The dies are heated to a temperature of 1200°C (2192°F) under vacuum according to a carefully controlled heating schedule.

The furnace is then allowed to cool and the dies removed from the furnace, because of the shrinkage accompanying densification, the rods are loose in the dies and can be easily extracted. This procedure yields rods with a diameter up to 30 mm (1·18 in.) and a length up to 40 cm (15·7 in.). The density of the product depends on the composition, for 4·6% C, it is as high as 96–97% of theoretical.

A comparison of the products obtained by hot pressing and by purely thermal sintering shows that at present the chemical stability of the former is better than the latter. We are now working to improve this chemical stability.

Compared to the cast uranium–carbon alloys, our products are characterized by finer grain size, random grain orientation, and the absence of dicarbide.

As these products are made at a 'low' temperature, it could be expected that they are in a non-equilibrium state and there is some evidence of this (*8*). Heat-treatment experiments have shown a definite grain growth but no practical volume change or new phase has been detected.

At present production of uranium alloys in the composition range near UC is sufficient to meet demand not only for research purposes but to supply complete fuel loads for new reactors (e.g. high temperature graphite moderated or organic-moderated) where they would replace uranium dioxide.

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GROUNDWORK—Accelerators

How are atomic particles accelerated and what velocities are attained?

In experimental nuclear physics, for the study of atomic structure and investigation into the existence of fundamental particles of nature, large machines are necessary for the production of fast atomic particles such as electrons, deuterons, protons, helium ions and mesons. Very great electrical voltages are needed for the acceleration of the particles, a problem that has tested the ingenuity of nuclear physicists since 1930 when Cockcroft and Walton devised an apparatus that yielded nearly a quarter of a million volts. The latest machine at the European Centre for Nuclear Research, CERN, in Geneva, produces particles with energies up to twenty-five thousand million volts.

In general there are two types of particle accelerators: **1.** Linear accelerators in which particles are accelerated in successive steps by either the direct production of high voltages or by an a.c. electric field produced by successive or continuous impulses; **2.** Cyclic accelerators in which particles are subjected to repeated acceleration in a circular path in a suitable magnetic field.

Accelerator Types

	Particles Accelerated	*Energy*
Linear		
Electrostatic generator	e,p,d,α	12 MeV (p)
Linear proton accelerator	p	68 MeV
Linear electron accelerator	e	1 BeV
Cyclic		
Cyclotron	p,d,α	40 MeV (α)
Synchrocyclotron	p,d,α	750 MeV (p)
Betatron	e	300 MeV
Synchrotron	e	1 BeV
Proton synchrotron	p	10 BeV

Electrostatic generators In the type of machine invented by Van der Graaff in 1931, charge is carried continuously by a system of conveyor belt and spray points to a spherical electrode to a high potential. The charge is sprayed onto the belt from a set of needle points and a rounded conductor by corona discharge. The development of high potentials is limited only by the corona discharge from the rounded surface of the dome. Particles are accelerated down an evacuated tube built within the generator using the high potential difference between the corona cap and the ground.

Linear accelerators Electrodes and gaps are arranged in a straight line, particles receiving successive increments of energy by varying proportionally the potential in the proper amplitude and frequency. In the a.c. drift tube accelerator (Fig. 1) charged particles are accelerated along a number of hollow tubes of increasing length fed from an ion source through a Van der Graaff generator or pre-accelerator. The frequency is so arranged that by the time a particle reaches the end of a negative tube the field has gone through half a cycle and the next tube becomes negative, resulting in a further forward impulse. The main advantage of this type of accelerator is the high beam intensity. The wave guide accelerator which can only be used for the acceleration of electrons relies on the steady accelerating field provided by an electromagnetic wave when it moves down a circular tube whose axis is parallel to the electric field of the wave. Electrons keep in step with wave movement the beam focused by an axial magnetic field.

Cyclic accelerators The concept of bending the paths of moving particles into circular orbits by magnetic field was developed to overcome the acceleration limitations of straight line designs.

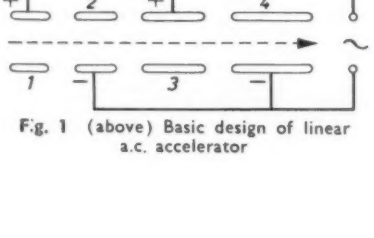


Fig. 1 (above) Basic design of linear a.c. accelerator

Cyclotron The principal portion of this instrument consists of two hollow semicircular electrodes shaped like the letter 'D'. A radio-frequency voltage is applied to the 'dees', each of which is insulated from the other. They are placed between the poles of a powerful electromagnet and contained in a vacuum chamber (Fig. 2). Gaseous ions (protons or deuterons) generated from an electric arc at the centre of the dees are accelerated by the alternating electrical field between the dees and travel a semicircular path under the influence of the magnetic field. On reaching the edge of the dees, acted upon by a positively charged deflector plate, the particles leave the vacuum chamber in beams of sufficient energy to burn up any target it strikes.

Synchrocyclotron To achieve greater energies than the cyclotron, the radio-frequency between the dees can be frequency-modulated to permit phase stability. In the cyclotron, as the particle velocity approaches that of light, relativistic mass increase results in the particles being out-of-step with the r.f. voltage.

Betatron The betatron was the first significant machine to produce very high energy electrons suitable for biological and medical research. As in the cyclotron, use is made of acceleration in circular orbit but an alternating magnetic field is employed so that acceleration only takes place as the variable field increases, thus overcoming the problem of mass increase, which with electron velocities that are so close to that of light, increases by a factor of 2·5.

Electron synchrotron The magnet in the largest betatron built is 1000 tons and, to reduce weight and at the same time improve performance, the betatron has been adapted so that by means of an alternating electric field applied in synchronism, an increasing magnetic field provides acceleration. The injected electrons are first accelerated up to a few MeV by using the betatron principle after which the constant r.f. potential and modulated magnetic field action are applied.

Acknowledgement to Prentice-Hall (New York) and Pitman (London) for use of figs. and table from Sarbacher's 'Encyclopædic dictionary of electronics, etc.'.

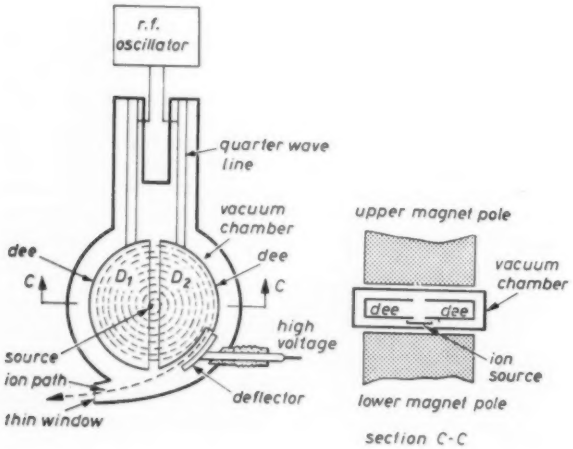


Fig. 2 (left) Plan view of cyclotron accelerator

UK COURSES

UKAEA Harwell Reactor School. Course for technical executives from OEEC member countries. July 4–15.

Imperial College of Science and Technology, London. Summer School in Health Physics—radiation protection. July 4 for two weeks.

Imperial College, London. Postgraduate course in nuclear technology (chemical) 1960–61. Full-time and of one year duration for graduates in chemical engineering, chemistry and metallurgy and suitably qualified applicants from industry. Fee: £64. Enrolment by June.

New Product Survey

EQUIPMENT · INSTRUMENTS · MATERIALS

NUCLEAR DATA ANALYSIS

high speed digital logger

Accurate measurement of the variations in temperatures, pressures and mechanical movements at a large number of points over a complete plant, or the analysis of data concerning neutron energy and scattering angle at a target depends very much on having a complete record of the variation of the pattern, or an indication when any factor strays outside preset limits.

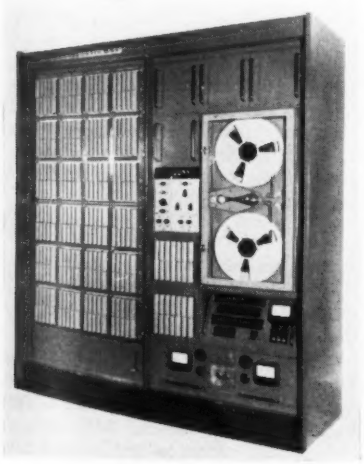
EMI has recently introduced a range of 'Emidata' high speed digital data analysers which provide a novel approach to the presentation of this data. They were originally developed in conjunction with the UKAEA for the high speed automatic histogram analysis of very large quantities of statistical nuclear data. These analysers employ the 'Emidec 2400' range of standard logic units and 'Emidata' magnetic tape decks.

The primary input data can come from the continuous scanning of a large number of tranducers in, for example, a chemical plant, and can be truly random in value and timing. The analyser will process this information at high speed and re-present it in sorted histogram form. In the case of the nuclear experiment the correlation of angle of scattering and energy yields valuable information about nuclear constants.

When the input data occur at a slow mean rate, it is often the practice first to accumulate the information still in unsorted form on magnetic tape, which is subsequently transferred to a centrally located analyser for high speed sorting. The output of these analysers can equally be in graphical or tabular printed form, or as punched paper tape or punched card, directly suitable for further computation in a conventional digital computer such as 'Emidec 1100'.

Tick **No 208** on reply card

The Emidata high speed digital data analyser



VACUUM MEASUREMENT

wide range pressure gauge

To meet the increasing demand for a general purpose McLeod vacuum gauge giving accurate and rapid pressure readings, the Measuvac has been introduced by Genevac covering the range from 150 millimetres to 1 micron. This is achieved by depressing a lever which gives accurate readings simultaneously on 2 scales, one reading from 2 millimetres to 150, and the other 1 to 2000 microns.

On depressing the handle mercury rises in three tubes and the rising level in the left-hand intake tube is adjusted to the set mark position. With this held steady a pressure reading is taken on the scale, appropriate to the pressure range. Once the reading has been taken the operating lever is released and the mercury returns automatically to zero ready for the next reading. This eliminates any possibility of mercury being left in the tubes and resultant damage if the pressure should rise to atmospheric.

Tick **No 209** on reply card

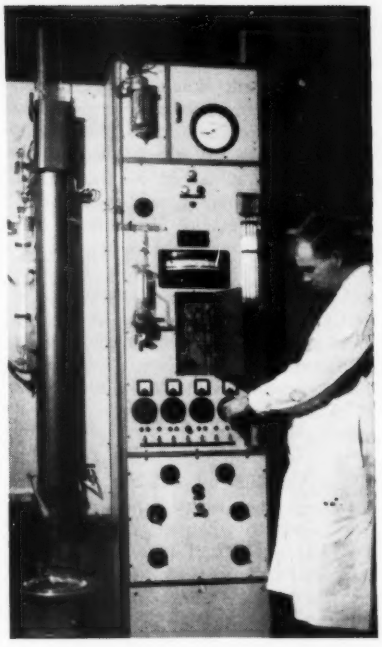
ORGANIC DISTILLATION

atmospheric or vacuum

A versatile unit for a wide range of laboratory distillation work in organic chemistry, particularly in the petroleum and solvents field, is being marketed by Winston Electronics.

The BP free-standing 14-plate atmospheric and vacuum distillation apparatus allows light gaseous components to be handled in the liquid phase by circulation of suitable refrigerant in the condenser and receiver system; and provision is made for the metering of incondensible gases.

The normal charge to the unit is 4 litres, which enables a sufficient quantity of each fraction to be obtained for subsequent analysis and refining treatment. The dimensions of the standard column are 36 mm internal diameter, 1370 mm length and 1220 mm packed length, the standard packing being stainless steel boot eyelets which gives a plate efficiency of 14. Alternative packings can be supplied to suit requirements and in special cases to considerably increase the plate efficiency. The column operates under adiabatic conditions.



BP's free-standing 14-plate atmospheric and vacuum distillation apparatus

The BP 14-plate equipment gives a sufficient degree of fractionation to enable yield data and curves of the significant properties of distillate fractions to be obtained, data required in most processes employing or producing organic liquids. Narrow boiling fractions can be analysed separately or blended in aliquot proportions to produce a number of possible refinery specification products for analysis, etc.

Tick **No 210** on reply card

EXAMINING METALS

shock-proof X-ray unit

A new lightweight, portable industrial X-ray unit of 300 kV capacity, known as the Baltospot G300D, has been introduced by Pantak Ltd. for examination of mild steel of up to 3 in. thickness. Both insulation and cooling of the X-ray tube in this unit is effected by a chemically and physiologically inert and non-inflammable gas. The use of this medium results in a lightweight tank head construction and achieves a high power/weight ratio, the weight being 142 lb. and the capacity being 300 kV. The unit can be supplied with either a conventional 40° solid angle beam insert tube with a fine focus, size 3·0 mm or a 360° circumferential radiation insert tube. Cooling of the anode is achieved in either case by forced circulation of the insulating gas by means of an internal blower.

The tube is protected against excessive temperature by a thermo switch mounted in the tank head. A further device in the control unit simulates the thermal capacity of the anode and gives the operator a visual indication of overheating so that a series of exposures can be planned without risk of overheating the tube. The maximum dimensions are 40 in. long × 9 in. diameter. When fitted with a protective cradle the weight is increased from 142 lb to 171 lb. The control unit is of the carrying case type, the maximum dimensions being 18 in. long × 14 in. wide × 8 in. deep. The weight is 60 lb.

The control operates from a 220 volts 50 cycles single phase supply and accommodates fluctuations of 10% either way. It is fitted with direct reading kilovolt and milliameters in addition to a synchronous timer which can be arranged for automatic repetition of exposures. The kilovoltage and tube current controls are of the stepless type giving continuously variable control.

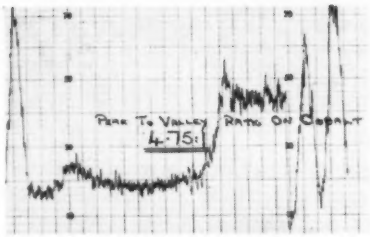
Tick **No 211** on reply card

GAMMA SPECTROMETER

crystal photomultiplier

A thallium-activated sodium iodide crystal, when mounted direct on a photomultiplier, gives a better resolution than when it is mounted in a windowed can and placed in contact with the photomultiplier. In the P1060 unit, a specially selected Hilger & Watts crystal, 3 in. in diameter and 3 in. thick, is mounted on the face of an E.M.I. type 9531 A photomultiplier and the whole unit is hermetically sealed in a cannister. The optimum e.h.t. voltage, determined experimentally, is specified for each assembly. Resolution, which is typified by a peak-to-valley ratio of 4:1 with a Co-60 source, will satisfy the needs of gamma-ray spectrometers requiring the best possible resolution.

The P1060 unit combines crystal with photomultiplier



A typical resolution curve with a peak to valley ratio of 4·75

Further, crystals 1 in. thick and 1 in. in diameter are being mounted on 1 in. E.M.I. type 9524 photomultipliers for use as detection probes. These assemblies are being selected for the highest counting efficiency and are likely to give a considerable improvement on the conventional canned-crystal units. Background radiation with these assemblies is due almost entirely to a small potassium impurity and will not normally exceed 8 counts/s.

Tick **No 212** on reply card

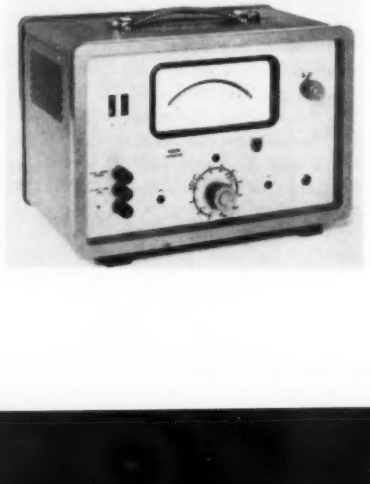
MILLIVOLTMETER

high sensitivity measurements

A new Philips d.c. Millivoltmeter, Type GM6020, has 11 voltage ranges (100 μV-10 V, full scale, with an input impedance of 1 Mohm); 11 voltage ranges (10 mV-1000 V, full scale, with an input impedance of 100 Mohm); and 22 current ranges (100 μμA–10 μA, full scale). Accuracy is 5% of full scale in the measuring range 0–100 μV, and 3% of full scale in all other measuring ranges.

The meter is automatically switched to the polarity of the voltage or current to be measured, which is indicated by means of two luminous columns. The instrument is fully protected against overloads and designed for connection to any existing mains voltage (40–100 c/s). Other features include: simple calibrating procedure by internal calibration voltage; a 5-inch linear scale with anti-parallax mirror reading; and very high and constant input resistance with low input capacitance. With a measuring probe v.h.f. voltages (0·1–800 mC/s) may be measured in the range 1 mV–16 V, and resistances of up to several megohms can be accurately measured with the aid of an external d.c. voltage.

Philips 6020 millivoltmeter has 11 ranges



Tick **No 213** on reply card

ULTRASONIC CLEANING

operates up to 160°F

Type 1156 Soniclean generator recently introduced by Dawe operates at 40 kc/s and delivers 250 watts peak power into either the complete tank and transducer (type 1160/T24) or into a stainless immersible transducer (type 1161/B18), both units capable of ultrasonically agitating 3 pints of cleaning solvent.

The transducers can be operated with liquid temperatures of up to 160°F. Operation at 100° to 160°F. is recommended for most cleaning applications. High temperature applications may be carried out by keeping the hot solution in a separate inner container and transmitting the ultrasonic energy through a water bath fitted with cooling coils.

Care must be taken with the choice of solvents in direct contact with the stainless steel since the chemical action of liquids which normally show only slight attack is considerably accelerated by the ultrasonic agitation. The common acids, sulphuric and hydrochloric, must not be used for direct contact with the tanks or transducers.

Tick **No 214** on reply card

IN BRIEF

• **Electronic capacitors** A wide range of polystyrene dielectric capacitors from Telephone Manufacturing Co. are available for computer storage purposes. In addition to metallized paper, metallized polyethylene terephthalate film capacitors are also available combining small size with high working voltages up to 125°C. For anode to grid coupling purposes, mica and polystyrene capacitors are particularly suitable.

Tick **No 215** on reply card

• **Steel cutting** A new method of cutting steel up to five feet thick in a matter of minutes employs a gas gun designed by British Oxygen Gases Limited. With this gun, which stabilizes the flame and inhibits flashback, the special qualities of propane gas which are ideal for deep cutting can be fully utilized.

Tick **No 216** on reply card

BUSINESS NEWS

CAUTION IS PARSONS THEME Another cautious note about developments in the nuclear field has been sounded — this time by *C. A. Parsons & Co. Ltd.* The annual statement by the chairman, Mr. F. W. Gardner, pointed out that 'some slowing down of the programme in this country combined with a considerable increase in the size of individual projects has reduced the number of contracts to be placed. There are too few for all the groups to obtain orders at intervals which are reasonable having regard to the heavy expenditure involved in maintaining them independently at a competitive level of efficiency'. Mr. Gardner went on to say that under the conditions facing the industry, pooling of resources and sharing of work between the two groups (*Nuclear Power Plant Company* and the *AEI-John Thompson Nuclear Energy Company*) greatly improved the prospects of carrying out future operations on a sound economic basis. The company's trading profit increased by £99,320 over the 1958 figure of £3,089,925.

UK-US BERYLLIUM MOVE *Chesterfield Tube Company* has appointed *Superior Tube Company* as its agent in the United States for the sale of pure beryllium tubing. Agreement has also been reached on an exchange of technical information on production and the applications of the tubing. It is expected that the arrangement will lead to a further increase in demand for Chesterfield's tubing.

BETATRON SALES IN THE UK *Pantak Limited* of Windsor, Berks, have concluded an agreement with *Sierex Limited* of London for the marketing and servicing of the Siemens 15 MeV Industrial Betatron.

RIO TINTO-DEGUSSA JOIN FORCES *Rio Tinto* and the German metallurgical group. *Deutsche Goldund Silber-Scheideanstalt* (Degussa) have joined together to form a new company to manufacture uranium and thorium fuel materials. The company is the *Nuklear-Chemie und-Metallurgie Gesellschaft mbH* (Nukem) and has already concluded a technical collaboration agreement with *Mallinckrodt Chemical Works*, which is also a shareholder.

Nukem will co-operate closely with Rio Tinto's uranium mining interests and with *Rio Tinto Dow Limited*. It will manufacture metallic, ceramic and cermet fuel materials; enriched uranium materials and conversion services; reactor fuel elements and plant and equipment for the production and processing of fuel materials and fuel elements.

Rio Tinto also recently acquired substantial shareholdings in the *Austro-Chematom - Kernbrennstoff - Gesellschaft mbH*. Other shareholders are *Degussa* and *Osterreichische Stickstoffwerke AG*. The Austrian firm will also manufacture uranium and thorium fuel materials and fuel elements and other operations in the nuclear fuel field.

COMPANIES JOINT RESEARCH MOVE General agreement on a joint programme of research and exchange of technical information and experience in the field of generating plant and ancillary equipment has been reached by *Associated Electrical Industries Limited, A. Reyrolle* and *Company Ltd.* and *C. A. Parsons* and *Company Ltd.*

CONTROL SYSTEMS AGREEMENT *Ferranti Ltd.* and the *Bendix Aviation Corporation* have an agreement on the sale in the US of the new Ferranti systems of machine tool control developed at Edinburgh.

BABCOCK PROFITS SLUMP The substantial fall in trading profit, from £3,097,382 in 1958 to £314,644 in 1959, recorded by *Babcock and Wilcox*, resulted mainly from the 'vast problems relating to the rapid emergence of atomic energy for power purposes', Mr. W. Lionel Fraser told shareholders in his annual review. The design, manufacture and erection of large power station boilers had always demanded the highest engineering skill but the difficulties associated with atomic power plant at this early stage of progress were even more incalculable, the chairman pointed out. However, in the long term the application of nuclear power was inevitable and it was vital that the company should continue to play its part in the reliable development of reactor systems.

LUBRICATING CONTRACT AWARD *Wakefield-Dick Industrial Oils Ltd.* have been nominated by the *Central Electricity Generating Board* as the supplier of lubricants for the nuclear power station to be built at Dungeness. The station is expected to become operational in 1964.

OVERSEAS

USES FOR DEPLETED URANIUM Industrial uses of depleted uranium were considered at a recent conference at Reno, Nevada. Aim of the conference was to review progress in various studies through which the *US Bureau of Mines* hopes to develop industrial applications.

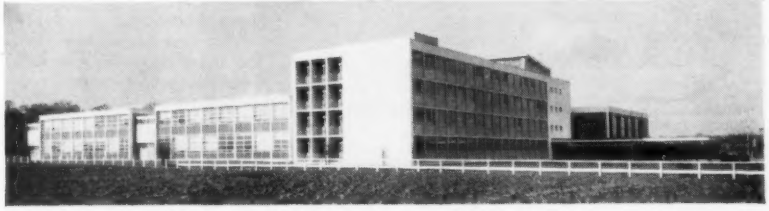
REACTOR CONTRACT AWARD *C. F. Braun and Company* have been awarded a contract on a cost plus fixed fee basis for building the Experimental Organic Cooled Reactor at the National Reactor Testing Station at Idaho.

BELGIAN INFORMATION DAY An International Information Day about Nuclear Energy is being held in Leige on June 9 by the *Belgian Association of Electrical Engineers*. Speakers will include Mr. C. A. Rennie, chief executive of the OEEC Dragon project.

CRYSTALLINE FUEL APPROVED Crystalline uranium dioxide fuel developed by the US *Spencer Chemical Company* is to be used in the Plutonium Recycle Test Reactor at the USAEC's Hanford Works, operated by the US *General Electric Company*. Hanford say that the material represents a significant breakthrough in the preparation of fuel. It will be fabricated into both swaged and vibrationally compacted Plutonium Recycle Test Reactor fuel rods (see *Progress in Industry* this month).

ASEA TURNOVER RISES The Swedish concern *ASEA* reports that its turnover in 1959 was more than eight per cent above that in 1958.

US RADIUM CORP SALES UP During 1959, increased sales were recorded by the *US Radium Corporation* throughout the company's entire range of products which includes radioactive products, and X-ray screens.



A view of the recently completed Standard Telecommunications Laboratories Limited (STL) building on the boundary of Harlow new town, Essex. Separated from the main building is the radio-chemical laboratory associated with the concern's 2 MeV Van de Graaf accelerator. The buildings were thrown open to visiting scientists, industrialists and educationalists at the beginning of May when demonstrations of aspects of STL's current research programme were given

SPECIALIZED EXHIBITIONS PROSPER

The general trade fair is giving way to the special-purpose exhibition, but deciding which to use is a problem for management

DOUBTS AS to whether British industry was correct to do away with the large general exhibition in favour of the specialist fair have been largely dispelled by the increase in the number of the latter, the extent of participation and the advance booking needed to acquire space. In addition, specialized exhibitions are assuming, more and more, an international character; the Instruments, Electronics and Automation Exhibition, for example, which is reviewed fully elsewhere in this issue, includes more than 100 exhibitors from overseas and in three years has grown to be the largest of its kind in the world.

The reason for this trend is partly due to the change since the war from a sellers' market to a buyers' one; consequently it has become increasingly important to industry to seek buyers particularly interested in its own products. With this trend has come rapid technological advance, the growth of whole new industries and the ever-increasing need for liaison and communication between buyers and sellers. What more logical method than a revival of the old market place—something that has been a basic human activity since the start of labour specialization. The move received its final impetus when a Federation of British Industries survey in 1957 showed that a large majority of those interviewed favoured the specialized exhibition.

THE MOBILE APPROACH Many firms are following the practice of building mobile exhibitions, like the one above owned by Standard Telephones and Cables Limited. The picture shows the interior of the unit which visits designers and engineers at their own locations and makes available the latest information on STC products. Being limited in size, the exhibition includes only a small cross section of the range of STC components, but apparently does prove a valuable complement to other sales methods

This, on the face of it, was against the trend on the European continent where the large general exhibition still flourishes. A particular example is the German Industries Fair held at Hanover from April 24–May 5. Here, however, the strict division into trade branches means, in fact, that a number of special trade fairs are held simultaneously. British participation at this fair was a record and success here for some groups has led them to rent a stand on a long-term lease — for example, the British Electronic Centre, which had fifteen member firms exhibiting of whom only one was showing for the first time.

Growth of exhibitions

With the ending of the British Industries Fair came the subsequent growth in the number of specialized exhibitions. This has now reached the point where some firms are asking: 'At which fairs should we exhibit?' There certainly are a number from which to choose; for instance, in the two months from the end of April to the end of June, there will have been 15 major exhibitions — approximately one every 4½ days.

Sir Christopher Steel (below), British Ambassador at Bonn, chats with Gunther Engelhardt (centre), German representative, and Mr. John Bray (right), overseas representative, during his tour of the George Bray exhibit on the British Electronic Centre stand at the Hanover Fair

While it appears comparatively easy to pick out fairs that one should and should not exhibit at, there is always the marginal fair — one at which a firm asks whether exhibiting there will in fact be a culmination of all their advertising campaigns in the technical press, by direct mail or other media.

There unfortunately appears to be no hard and fast rule. In some overseas fairs such as Brno in Czechoslovakia, the decision is made by the host country as to which firms should take part. Behind this is the fact that in these cases, the host country buys all the exhibits and avoids unnecessary purchases.

For the larger firm, the problem can be solved by having a stand at a 'marginal' exhibition and from this, estimate whether it would be worthwhile exhibiting again. For the smaller firm, however, exhibition staffing is a problem which can lead to overstraining of resources and a build-up of work in head offices for executives spending time at the stand.

One consideration they must take into account is whether exhibitions justify themselves. Figures quoted by Mr. W. H. Waller, assistant exhibitions organizer, Fairs and Exhibitions Limited, show that in general 80% of firms showing at established fairs and exhibitions do very well; 10% do indifferently and 5–10% do very badly.

The last figure, says Mr. Waller, is caused by factors not connected with the exhibition — or else the figure of 80% would be much lower. The factors that could account for a bad showing include market research—a firm having a stand to see if the exhibition was worthwhile —or staffing, for using temporary staff on a stand, says Mr. Waller, usually proves fatal.

Key factors

Other questions that have to be answered are:

(a) 'Are our competitors exhibiting?' This may seem like keeping up with the Jones' but in fact it is a good guide for their presence means that they must think it worthwhile.

(b) 'Have we a new product to show?' American buyers, in particular, place emphasis on this. Their point of view is that most people look for something new at fairs and that it is always wise to emphasize new products or new features of standard products.

(c) 'Have we trained staff to spare?' According to Mr. Waller and other organizers, this is a crucial point. The visitor, they say, spends time examining a product, comparing its appearance, size, cost, etc. with similar products and wants to have technical questions answered and to discuss points on the spot. Inability to provide the answers is fatal. Consequently, where trained staff are not available, it is probably better not to exhibit.

These are considered to be key factors but even when the answers are satisfactory, there is no guarantee of success for any particular exhibit at a fair. It depends on the product, geographical location of the fair, stand design and construction and preliminary advertising beforehand both by the firm and the exhibition organizers so that the potential customer knows of the company and makes a point of seeking it out at the fair.

But there is little doubt that the specialist trade exhibition is here to stay and will continue to develop. It provides a convenient and efficient means of presenting a variety of goods so that the buyer can see them in a comparatively short space of time. This alone would justify its continued existence.

from **HIGH VOLTAGE ENGINEERING . . .** the most complete line of supervoltage and high energy radiographic equipment for non-destructive testing and . . . .

EVALUATION OF REACTOR MATERIALS AND COMPONENTS . . . .

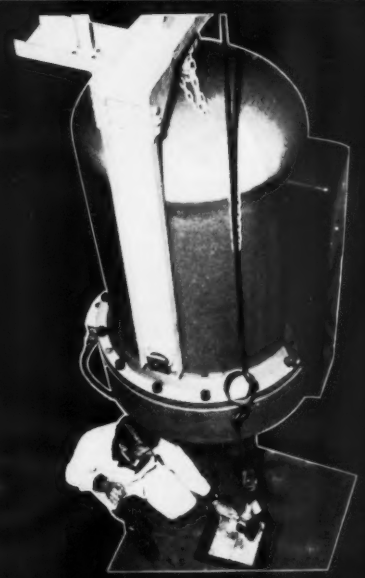
. . . 1 to 15 Mev X-Rays for high-speed, precise radiographic examination of special nuclear materials including high-density alloys, fuel elements, heat exchangers, pressure vessels, valves, control mechanisms *to meet rigid government inspection standards.*

SUPERVOLTAGE

- 1 and 2 Mev Van de Graaff X-Ray Generators
- Penetration: ½" to 11" equivalent steel thickness
- Mount Options: Fixed, truck, or flexible crane

Performance Characteristics

Model	Energy (Mev)	X-Ray Intensity 1 meter from source (r/min)	Focal Spot (mm)
JR	1	8	1
AR	2	75	1



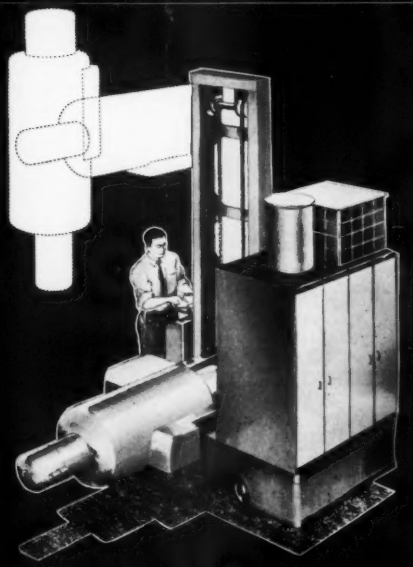
Model JR, 1 Mev Van de Graaff x-ray generator used for inspection of fuel elements. Courtesy Babcock & Wilcox Co.

HIGH ENERGY

- 8-15 Mev Linac X-Ray Generators
- Penetration: 2" to 25" equivalent steel thickness
- Mount Options: Fixed, truck, or flexible crane

Performance Characteristics

Model	Energy (Mev)	X-Ray Intensity 1 meter from source (r/min)	Focal Spot (mm)
LR-8	8	1500-6000	1-5
LR-12	12	2300-18000	1-8
LR-15*	15	3000	1



8, 12, or 15 Mev High Energy microwave Linear Accelerator for radiography (truck-mounted).

**Designed for solid rocket propellant inspection.*

Write for Technical Brochure "High Energy Radiography in the 6-30 Mev Range."

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Points from Papers

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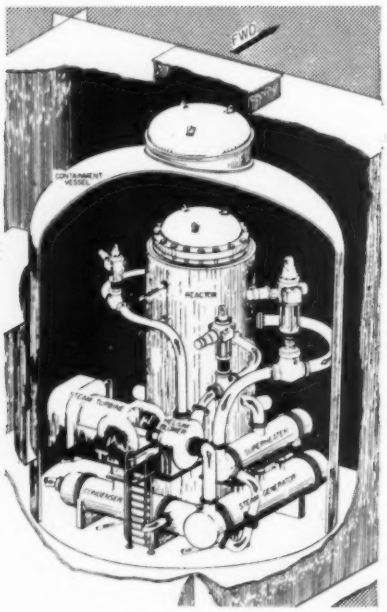
PRE-TESTING MARINE REACTORS

An evaluation of techniques for pre-testing and installing nuclear prototype power plants in merchant ships has recently been made by the Ford Instrument Company and Maryland Shipbuilding and Drydock Company for the US Maritime Administration. In presenting the results of the study, report FICo 112 (TID 4500) selects an optimum technique having the widest general application and applies this concept to a reference 32,790 dwt tanker and gas/superheated steam nuclear power plant.

The reference ship, a three-island bulk oil tanker of 661 ft length with a service speed of about 17 knots, has a normal shaft horsepower of 13,600 at 97 rpm. The steam generating plant consists of two oil-fired, force draught boilers, each capable of delivering 53,000 lb/hr of superheated steam at maximum rating. The closed pressurized primary loop of the reference nuclear power plant consists of a gas-cooled reactor, a steam generator with a superheat unit, and a steam turbine-driven helium blower.

Four schemes for test vehicles were examined in terms of new construction and conversion of general cargo and passenger cargo ships with two methods of installing the reactor and auxiliaries in these vehicles: direct and indirect. With the latter the equipment is erected elsewhere and then transferred as a unit into the test vehicle.



Gas cooled nuclear power plant for 33,000 dwt bulk oil tanker

The testing programme allows for: (1) pre-installation inspection and testing, (2) pre-critical testing, (3) initial criticality tests, (4) power operation of nuclear power plant, and (5) power operation of nuclear propulsion system.

For the technique of ship conversion, two new, full-beam, adjacent cargo tank sections would be constructed with the reactor, auxiliaries, and contaminant installed in the centre tank of the forward section. This test vehicle would then be towed to a shore test site for the nuclear power plant tests, after which it would be installed in the ship.

For new ship construction, two adjacent, full-beam cargo tank sections would also serve as the test vehicle. The ship's hull would be built and launched with a transition piece in way of these missing cargo tanks, nuclear power plant testing to be carried out as above.

A detailed account is given of some of the major operations involved in constructing the reactor test vehicle and installing in the reference ship, together with an overall nuclear conversion schedule and cost summary.

NON-NUCLEAR USES OF URANIUM

Substantial stocks of uranium from which most of the fissionable U235 isotope has been removed are rapidly accumulating. Faced with the problem of disposal, the USAEC have now removed restrictions on the non-nuclear uses of depleted uranium and have made it available in the form of uranium hexafluoride. To acquaint the public with some of the properties and uses, assuming that anywhere from 10,000 to 20,000 tons could be made available annually for industrial applications outside the nuclear field, Battelle Memorial Institute have written a report TID-8203.

In the chemical field, applications that are suggested include use in photography for improving solutions and as a mordant for dye toning films; the purification of gases; as an analytical reagent in the determination of substances such as phosphates, cinnamic acid, phenols, and arsenates; and its use in pigments and for colouring paints, varnishes, dyes and stain. A wide variety of applications also exist for uranium-containing catalysts.

Apart from the ability of uranium to purify inert gases and clean up gaseous impurities in vacuum tubes and gas-discharge devices, it can be used in photoelectric cells for the detection of ultraviolet light and as a material for targets in X-ray tubes. In the further development of semiconductors, particularly for use at high ambient temperatures, there is a potential for some of the uranium compounds.

The metallurgical industries offer a large potential use particularly as an alloying agent in steel to increase hardness. The use of uranium for scavenging certain materials in the ferrous and non-ferrous fields is considered worthy of exploitation. Its use in making an improved tungsten-base metal also offers an interesting possibility.

The most promising shielding applications of depleted uranium are gamma-ray shielding in situations where minimization of shield size and weight is of major importance such as: containers for dispatch of spent nuclear fuels and for radioactive isotopes; for shielding in radiation therapy devices; and in hot laboratories.

FUEL PROCESSING

The AEC plans to process, at existing AEC facilities, spent fuels from civilian reactors, until such service is available from private industry. In welcoming visitors to the AEC Symposium held at Richland, Washington, October 20–21, 1959, Mr. J. E. Travis, Manager of Hanford Operations Office, said 'the problems that the power reactor fuel elements and blanket materials present to the chemical processing field are, in many cases, unprecedented. The chemist will have to tax his ingenuity to the utmost to devise flow sheets to process these materials, which are certainly not designed to make this job easier.'

The discussion of the problems of 'Chemical Processing of Irradiated Fuels from power, test, and research reactors', the subject of the symposium (Report TID-7583) was widely ranged. The discussion of American practices covered the Hanford, Idaho, Savannah River, and Oak Ridge plants; whilst operations at Chalk River included mechanical handling. From the European viewpoint, Mr. Tuohy gave details of the UK civil power programme and an account of Eurochemic was presented by Mr. Detilleux.

New Reports

Power cost normalization studies, Civilian power reactor programme — 1959 USAEC January 1960 (Report SL-1674). Available from OTS at $2·50 or depository library.

Magnetohydrodynamic flow. Edward A. Sottysik. University of California. November 1959. Report UCRL-5722. Available from OTS $1·00 or depository library.

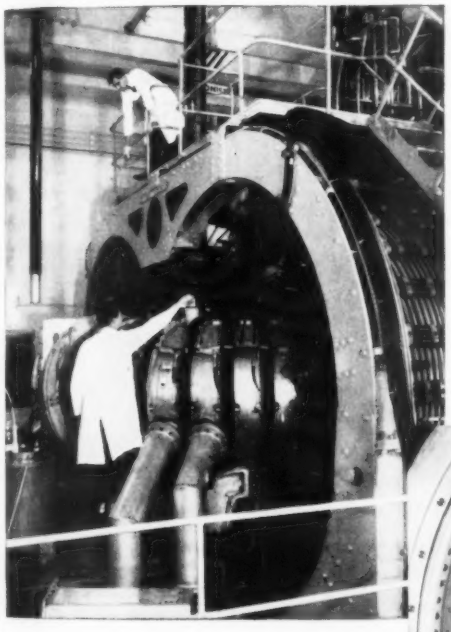
Summary report—phase 1, graphite-matrix nuclear fuel elements. National Carbon Co. December 1959. Report ORO-240 (Vol. 1). Available from OTS $2·75 or depository library.

Development of high-strength corrosion-resistant zirconium alloys. J. A. De Mastry and others. Batelle Memorial Institute. February 1960. Report BMI-1418. Available from OTS 75 cents or depository library.

TEDDINGTON BELLOWS
and Nuclear Power
HARWELL PAYS A TRIBUTE

Harwell top research scientists have freely acknowledged * that recent improvements in the operational efficiency of Zeta owe much to the introduction of a corrugated stainless steel liner inside the aluminium 'torus'. Having decided to use such a liner, they turned to Teddington engineers who, out of their experience in adapting their bellows expansion joints to various demands in a wide field of industry, produced exactly what was required for satisfactory running over long periods.

* *In a paper read before the I.t.E. on 29/30 April 1959 by Mr. J. T. D. Mitchell of the U.K.A.E.A., Harwell*



In Zeta, experiments towards controlling fusion have resulted in gas temperatures of several million degrees centigrade being achieved for millisecond periods. View showing the torus.

This stainless steel liner has improved operational characteristics and requires less maintainance than the original aluminium liner system. Here is part of the twelve welded sections of Teddington stainless steel bellows tube of wall thickness 0·017″; it has 2½ convolutions per inch of a depth of 0·75″. The bellows is 38 inch bore and the whole toroidal bellows assembly has an axial length of 37 feet and an electrical resistance of 0·02 ohms.

SEND FOR HANDBOOK R. 63

Illustrated descriptions are given of the many and varied problems that Teddington Bellows Expansion Joints can overcome. If you did not secure your copy at the Engineering Exhibition, please write for one.

ZETA

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Diary

23–28 MAY
International Instruments, Electronics and Automation Exhibition at Olympia, London, W14

24 MAY
Annual General Meeting, The Society of Instrument Technology 6.00 at Manson House, 26 Portland Pl., London, W1

24–26 MAY
Electronic Forum for Industry Conference at Olympia, London Details from The Electronic Engineering Association, 17 Fleet Street, London, EC4

24–27 MAY
Exhibition of Drawing Office and Photocopying Equipment Lawes Rabjohns at Ealing, London

25 MAY
Stable frequency generation Symposium British Institution of Radio Engineers 3.00 in the Gustav Tuck Theatre, University College, London

25 MAY
Luminescence — the cold light of physics G. K. J. Garlick 9.00 pm at the Royal Institution, 21 Albemarle Street, London, W1

30 MAY—2 JUNE
First International Pipes & Pipelines Exhibition at Earls Court, London, SW5

5–9 JUNE
Sectional Meeting of the World Power Conference in Madrid. Applications to the Secretary, British National Committee, World Power Conference, 201–2 Grand Bldgs., Trafalgar Sq., London, WC2

7–13 JUNE
IAEA Radiation Dosimetry in Health Physics, Vienna

10–26 JUNE
British Exhibition and Trade Fair at the Coliseum Exhibition Building, New York, USA

11–25 JUNE
30th International Trade Fair, Poznan, Poland

12–15 JUNE
Sixth Annual Meeting of the American Nuclear Society at Chicago, Illinois, USA

13–15 JUNE
International Powder Metallurgy Conference. Metal Powder Industries Federation, American Institute of Mining Metallurgy & Petroleum Engineers at New York, USA

15 JUNE
The Strength of Solids A. H. Cottrell 9.00 pm at The Royal Institution, 21 Albemarle Street, London, W1

15–29 JUNE
Seventh International Nuclear Congress and Exhibition on Electronics and Atomic Energy National Committee for Nuclear Research at Rome, Italy

18–29 JUNE
Exhibition and demonstration of British Scientific Instruments at The Polytechnic Museum, Moscow Details from SIMA, 20 Queen Anne Street, London, W1

22 JUNE
Visit to Amersham Radiochemical Centre Society of Chemical Industry members leave London at 10.30

23 JUNE
Symposium on Analytical Chemistry of Beryllium, UKAEA Industrial Group at Blackpool

27 JUNE—6 JULY
First International Congress on Automatic Control Moscow Details of papers from Institution of Electrical Engineers

28 JUNE—1 JULY
63rd Annual Meeting of American Society for Testing Materials, Atlantic City, New Jersey

Further Ahead

21–27 JULY
Third International Conference and Exhibition on Medical Electronics. Held jointly by the International Federation for Medical Electronics and The Institution of Electrical Engineers at the Empire Hall, Olympia, London

25 JULY—6 AUGUST
12th General Assembly of the International Union of Geodesy and Geophysics, Helsinki

26 JULY
Associated Electrical Industries Research Laboratories, Aldermaston Royal Society visit leaves Burlington House at 9.00 Accommodation for 40 persons Bradwell Nuclear Power Station Royal Society visit leaves Burlington House at 10.00 Accommodation for 40 persons

8–12 AUGUST
IAEA Effects of Ionizing Radiation on Seeds and its Significance on Crop Improvement Probably at Karlsruhe

15–25 AUGUST
21st International Geological Congress, Copenhagen

23–25 AUGUST
1960 Cryogenic Engineering Conference University of Colorado and National Bureau of Standards at Boulder, Colorado

24–28 AUGUST
Institution of Production Engineers Symposium on machine tool control systems, College of Aeronautics, Cranfield

25 AUGUST—3 SEPTEMBER
Tenth International Conference on High Energy Nuclear Physics. International Union of Pure & Applied Physics and Commission on High Energy Physics at Rochester, New York, USA

29 AUGUST—2 SEPTEMBER
USSR Academy of Sciences — UNESCO Symposium on initial effects of radiation on living cells. Moscow

29 AUGUST—3 SEPTEMBER
International Conference on Nuclear Structure at Queen's University, Kingston, Ontario, Canada.

31 AUGUST—11 SEPTEMBER
St. Eriks Fair, Stockholm. Capital and consumers goods, with specialist sections

31 AUGUST—7 SEPTEMBER
Annual meeting at Cardiff of the British Association for the Advancement of Science

1 SEPTEMBER
Rocket and Satellite Instrumentation One day symposium by the Society of Instrument Technology and the British Interplanetary Society in London

5–9 SEPTEMBER
IAEA Conference on medium and small power reactors, Vienna

10–17 SEPTEMBER
5th International Instrument and Measurements Exhibition and Conference, Stockholm Details of UK and AEA exhibits from NETAC, 32 Victoria Street, London, SW1

INDUSTRIAL LITERATURE

Engineering materials. The 1960 edition of 'The Engineer' Buyers Guide, confined to firms advertising in 'The Engineer' or the 'Buyers Guide', now contains over 34,750 entries arranged under approximately 2,650 classified headings including chemical plant, electrical equipment, engines and engine parts, machine tools and accessories, and sheet metal working machinery.

Tick **No 226** on reply card

PVC plastics. British Geon have issued a booklet describing the properties, forms and uses of 'Geon' the trade name for polyvinyl chloride and other members of a family of vinyl plastics raw materials.

Tick **No 227** on reply card

Aluminium welding. A publication from the Swedish AB Svenska Metallverken describes facilities for fabricating and installing welded components in nuclear reactors, particularly large aluminium structures.

Tick **No 228** on reply card

Lead development. Progress in new developments, sponsored by the Lead Development Association, are reviewed in their report for 1959.

Tick **No 229** on reply card

Atomic energy. The March issue of 'Fairey Review' contains a 'plain man's guide to atomic energy' by the General Manager (Heston).

Tick **No 230** on reply card

Pressure vessels. Hadfield's new brochure outlines facilities available for the manufacture of forged and cast vessels and other products.

Tick **No 231** on reply card

Engineering manufacturers. 'The British Engineers' handbook 1960' consists of a classified handbook of members, their products, trade names and trade marks. The index to manufactures is in English, Portuguese, French, German and Spanish.

Tick **No 232** on rep'y card

Corrosion resistant metals. The latest booklets from ICI Metals cover the mechanical and physical properties, corrosion resistance, fabrication and weight tables for titanium, zirconium and hafnium.

Tick **No 233** on reply card

Japanese 150 MW reactor. The many unusual design problems, control and safety aspects and main station data for Japan's first nuclear power station designed by GEC for Tokai-Mura are described in a brochure reprint of NUCLEAR POWER articles. A coloured sectional drawing is included.

Tick **No 234** on reply card

Non-destructive testing. LEGPA of Paris, in a recent leaflet, outline a range of instruments for non-destructive inspection of metals including bars, tubes and other shapes, corrosion effect in pipes, ropeway cables and steel fabrications.

Tick **No 235** on reply card

Water treatment. An introductory leaflet from Head Wrightson describes the properties of a range of water softeners being made under licence to Belco.

Tick **No 236** on reply card

Automatic electric controls. Londex's new booklet which gives summarized data on their current range of relays, counters and controls also includes pressure switches, flow indicators and level controls for both solids and liquids.

Tick **No 237** on reply card

Thermocouple data. The current range of thermocouples and compensating cables, together with two new types of thermocouple jointing heads, are dealt with in the latest information sheet from Pyrotenax.

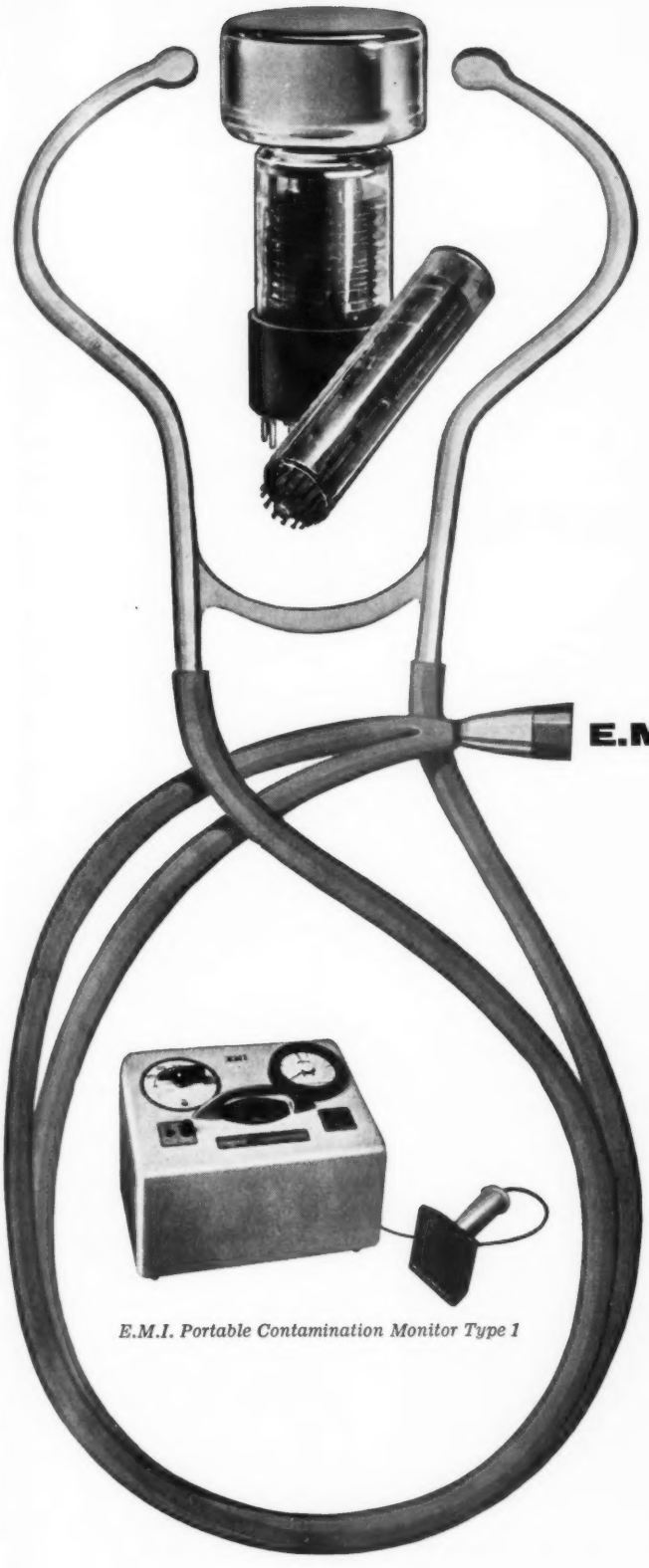
Tick **No 238** on reply card

Thermionic valves. The latest application reports from Standard Telephones cover the high mutual conductance triode and an R.F. beam power amplifier.

Tick **No 239** on reply card

Motors for hoists. A leaflet from Lancashire Dynamo gives a selection of motors that have been designed for special requirements in cranes, hoists and lifts.

Tick **No. 240** on reply card



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H.R.H. Prince Philip meets Dr. R. W. Pringle, chairman of Nuclear Enterprises (GB) Ltd. on a recent visit to the company's laboratories and works on the outskirts of Edinburgh. Human Body Monitors for the measurement of radioactivity were singled out by Prince Philip during his tour. Others in the picture include the Lord Provost of Edinburgh; and Mr. R. Pringle, a director

People

by John Radford

Research reactor requirements in more than seven countries will be discussed by **Mr. Deryck Baines,** sales manager of Hawker Siddeley Nuclear Power Company Ltd. during the seven-week world tour he started on April 10. I also understand that the uses of impermeable graphite both in and outside the nuclear field will be another topic of conversation. Mr. Baines' tour will take him to Canada, Japan, Australia, New Zealand, India, Pakistan and the Middle East. Holding the 'fort' during his absence is **Dr. J. M. Conway-Jones,** Applications Engineer.

New head of the European Nuclear Energy Agency's Economic Office is **Dr. Heimo Hardung-Hardung** who was, I recall, former Technical Sales Manager of the Nuclear Group of the Deutsche Gold und Silber Scheideanstalt (Degussa).

From equipment engineer to director in thirteen years is the success story of **Mr. M. L. Jofeh,** manager, Industrial Division, Sperry Gyroscope Co. Ltd. I learned of his appointment as a director early in May. Mr. Jofeh joined Sperry in 1947 as an equipment engineer and subsequently headed the engineering unit at the company's Stonehouse (Glos.) factory before returning in 1954 to Brentford head office to take up the position of Deputy Chief Engineer. Appointments as Chief Engineer and Manager of the newly-formed Industrial division followed, the latter taking place in January 1959.

Thirteen may be considered an unlucky number but I see that there is another thirteen year success story to record—that of **Mr. John Willsher,** General Works Manager of George Kent Limited who has been appointed to the company's Board of Directors. Now only in his early forties, Mr. Willsher joined the company in 1947 after service in the

MR. HIND
Rises to
Directorship

MR. WILLSHER
Lucky
Thirteen

Army and by 1951 was Production Controller. The next year he was Production Manager and from 1955 to early 1959, he was Instruments Division Manager before his appointment as General Works Manager.

Mr. C. J. Hind, who since 1957 has been Chief Engineer (Engines) at Ruston & Hornsby Ltd. of Lincoln, has been appointed Engineering Director. Mr. Hind, I hear, received his early engineering training with Rustons, devoting the latter part of his training to high speed engine design. In 1940 he was transferred to an associate company, Davey, Paxman & Co. Ltd. After the war, he became Chief Experimental Engineer to Dennis Brothers & Co. Ltd. and in 1949 returned to Davey, Paxman as Chief Designer. In 1953, he became Paxman's Chief Diesel Engineer.

Recently appointed to the post of Sales Development Manager of Semiconductors Ltd. was **Mr. P. A. Charman** who joined the company when it was formed in 1957 to build up the technical sales organization. I note that one of his chief responsibilities will be dealing with technical aspects of customers' needs, especially in their long-range planning.

MR. CHARMAN
Long Term
Planning

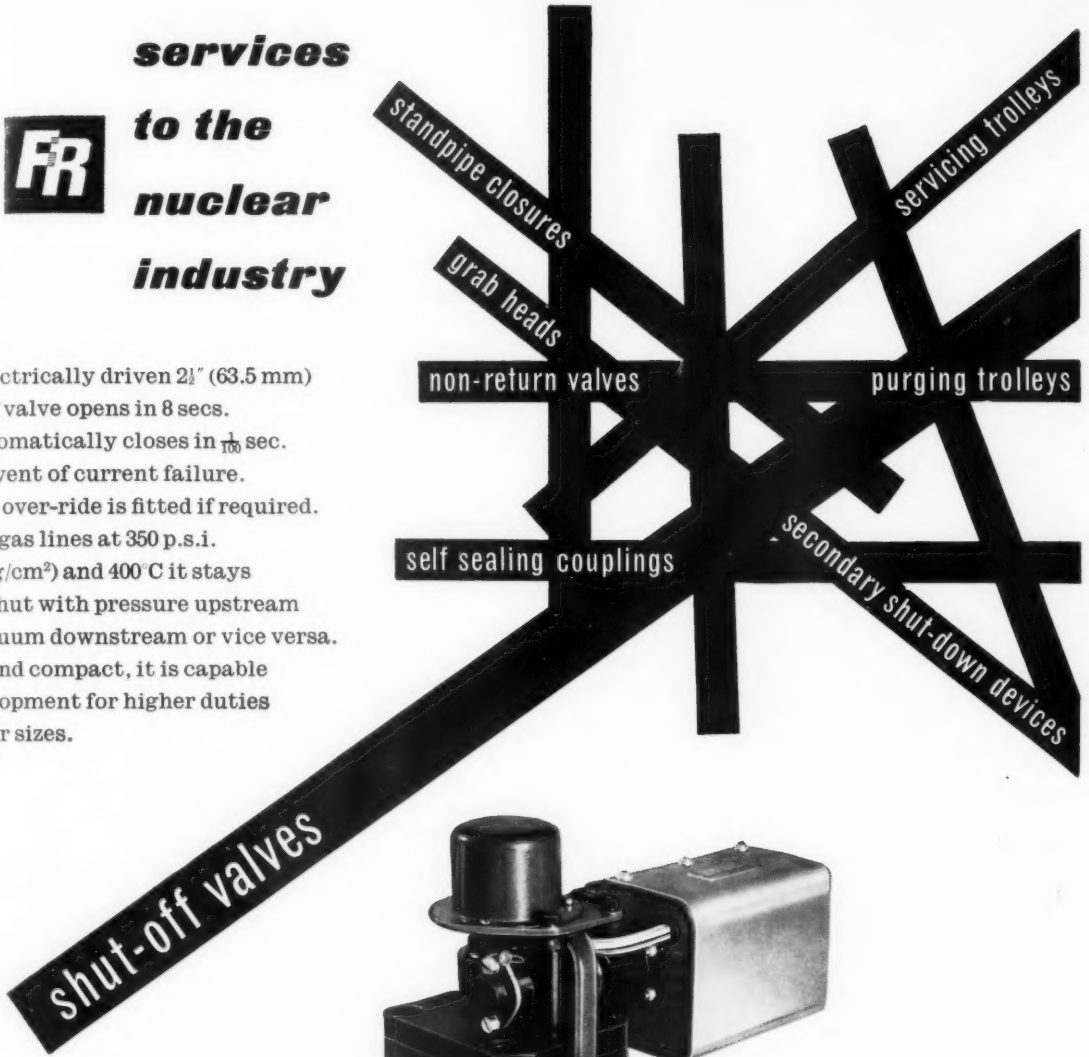
MR. RINGROSE
Promotion at
Semiconductors

Another appointment made by Semiconductors has been that of **Mr. J. W. Ringrose** as Chief Applications Engineer. He will be taking charge of the company's Applications Laboratory which is being expanded to meet increased demands.

Visiting West Germany and Scandinavia on behalf of the Gresham-Lion group is **Mr. R. W. Hardisty** who is also secretary of the Electronic Components Centre (Great Britain) Ltd. Mr. Hardisty told me: 'I am visiting various centres where interest has been shown in the Lion 'Nanoscope', particularly in West Germany and Scandinavia. My previous tour in Holland, Switzerland and France convinced me that demonstrations on the customer's 'home ground' can achieve the best results'.

Due to health reasons, **Mr. J. W. Plowman** has resigned his Directorship of Dewrance and Co. Ltd. I understand that **Mr. B. S. Bass,** previously Sales Manager, has been appointed to the Board as Sales Director.

services to the nuclear industry



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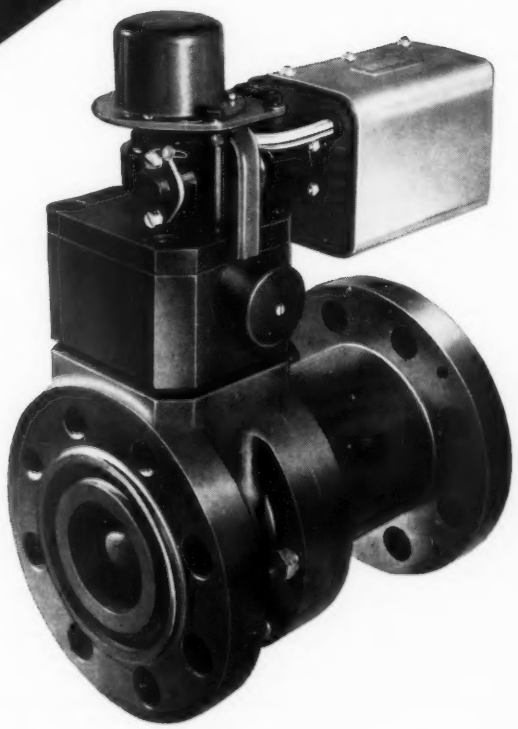

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Book Reviews

Low temperature systems

Cryogenic Engineering by Russell B. Scott. Princeton and London, 1959: D. Van Nostrand Company 368 pp Price 42s

Cryogenic (or low temperature) engineering deals with processes and equipment which operate at low temperatures extending into the range of liquid oxygen, liquid hydrogen and liquid helium, which have normal boiling points of 90°K, 20°K and 4°K, respectively. It is traditionally concerned with the liquefaction and separation of gases and it has expanding applications in electronics, nuclear physics (e.g. liquid hydrogen bubble chambers for detecting nuclear particles), thermonuclear devices and rockets and space vehicles employing cryogenic liquids, whether propelled by chemical fuels or nuclear energy.

This is the first text book on cryogenic engineering and there is a great need for it. It follows shortly after engineering experience, long established at liquid air temperatures, was recently extended to liquid hydrogen temperatures. It was appropriately written in the U.S.A., the author being head of the large Cryogenic Engineering Laboratory of the N.B.S. It achieves its stated objective of presenting basic and applied information in sufficient detail for immediate use in the study of new cryogenic systems.

Because of the drastic variations of physical properties (mechanical, thermal and electrical) of fluids and structural materials at these temperatures, and because of special problems, such as thermal insulation, there is an increasing need for basic physical data and the development of advanced techniques and equipment, especially for liquid hydrogen and liquid helium systems. There is a mass of such information with detailed drawings of equipment in the chapters on Insulation, Storage, Transport and Transfer of cryogenic liquids, covering both laboratory and large-scale conditions.

The two final chapters give the relevant physical properties and temperature-entropy diagrams for oxygen, nitrogen, hydrogen and helium (including solid states) and most of the relevant physical properties for the important structural materials.

The first five chapters are a thorough introduction to cryogenic engineering, extending into the temperature range below 1°K and describing the established processes, experimental techniques and special problems encountered, rather than the development of engineering equipment.

Physical principles and underlying theory are presented clearly throughout the book, with detailed descriptions of experiments, long lists of references and a total of 202 figures and 85 tables. This is an essential book for all engineers and practising physicists involved with low temperatures.

W. H. Denton

Elementary nuclear physics

Introductory Nuclear Theory by L. R. B. Elton London 1959: Sir Isaac Pitman & Sons Ltd 286 pp Price 40s

This book is a development of a final honours lecture course, and covers most topics in elementary nuclear physics. Starting with a general description of the basic facts—sizes and binding energies of nuclei, and of such things as magnetic moments, angular momentum, and isotopic spin, it continues with a discussion of nuclear forces (primarily the low-energy interaction), models of nuclei, and elementary reaction and disintegration theory. The three final chapters cover photon reactions, beta-decay, and elementary pion theory.

The development is clear and straightforward and, while quantum mechanics is used throughout the physical picture is borne in mind and experimental numbers are quoted frequently. Some additional mathematics—time-dependent perturbation theory, and the Dirac equation—is given where it is necessary for the subject-matter and, on the whole, one is not referred much to other texts for special results.

The reviewer would have preferred a different emphasis in parts. For example, the collective model is dismissed in just over a page, and no mention is made of the astonishing rotational energy sequences. On the other hand, seven pages are devoted to the theory of multipole transitions, and six to the photodisintegration of the deuteron. However, these are devoted to the theory of multipole and are not serious defects.

J. K. Perring

New Books

- *Concise Dictionary of Science* Physics, mathematics, nucleonics, astronomy, chemistry by Frank Gaynor London 1959 P. Owen 546 pp Price 50s.
- *Metal Industry Handbook and Directory, 1960* London 1960 Iliffe 584 pp Price 21s.
- *Kempe's Engineers Year-book 1960* 2 volumes (with index) London 1960 Morgan Bros. Price 87s. 6d.
- *Glossary of Atomic Terms* Prepared by the Technical Writers Section, UKAEA London 1960 H.M.S.O. 54 pp Price 3s. 6d.
- *Who's Who in Atoms* An international reference book, 1960 edition now in two volumes edited by A. W. Haslett London 1960 Vallancey Press Price £10 10s.

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NEW BOOKS
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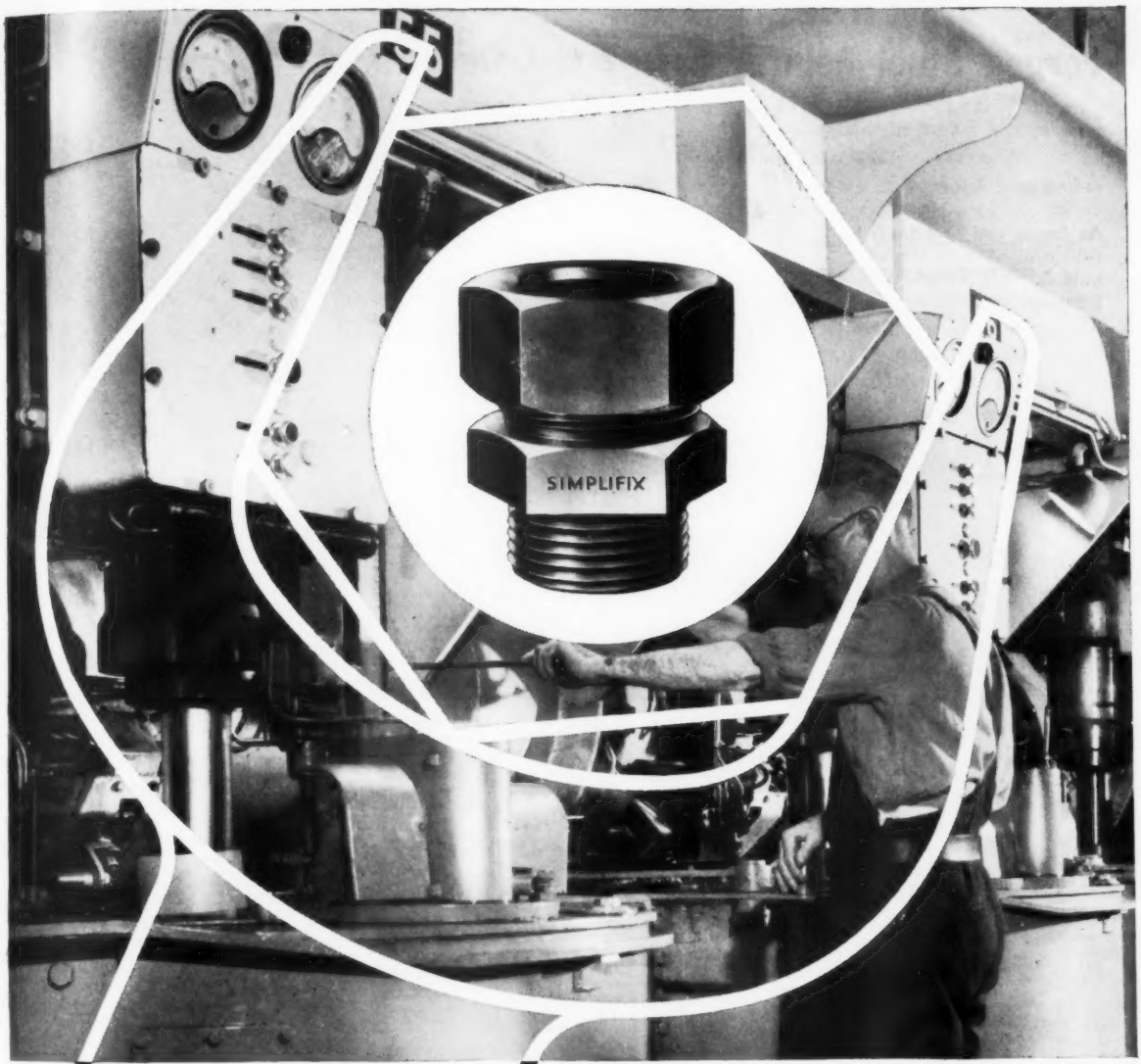
MASSON ET Cie—Erratum à l'annonce parue dans NUCLEAR POWER (Vol. 5. No. 48—Avril 1960)

Lire :

MM. MASSON & Cie sont dépositaires pour la France de toutes les publications de l'AGENCE INTERNATIONALE DE L'ÉNERGIE ATOMIQUE.

(et non: Agence européenne)



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As machined prior to installation 98″ o/d, 68″ i/d, overall width 24″ (by courtesy of Whessoe Ltd.)

As forged and heat treated 101″ o/d, 65″ i/d, overall width 27″ (by courtesy of Whessoe Ltd.)

As machined prior to installation for 3′ 3″ bore inlet duct and duct erection opening for heat exchangers (by courtesy of International Combustion Group)

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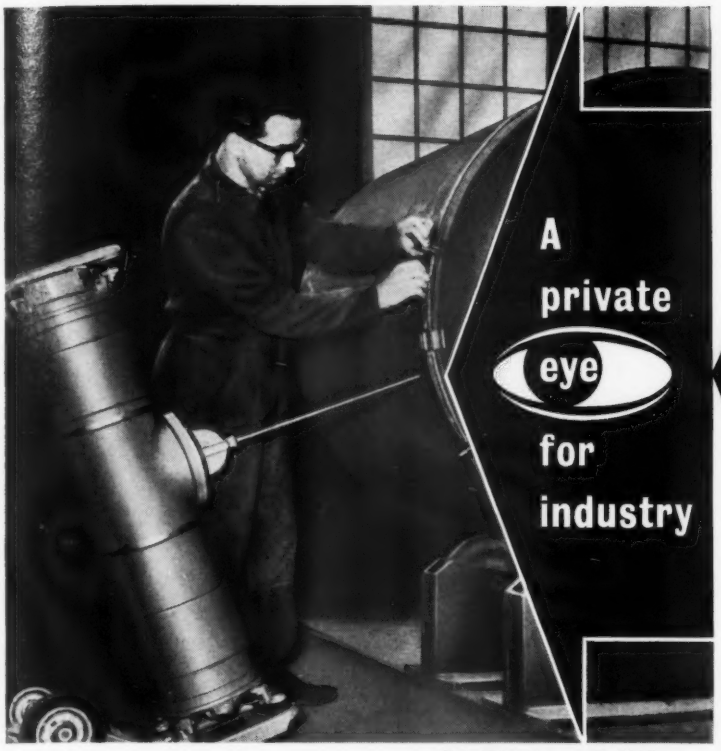

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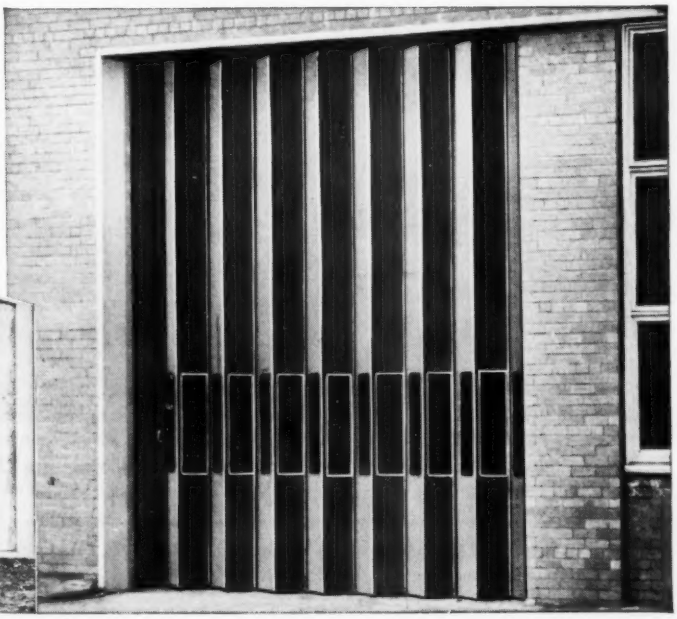

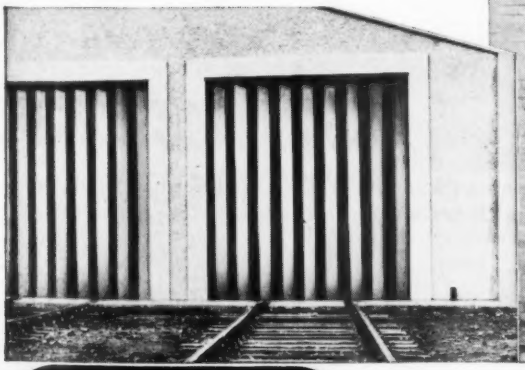

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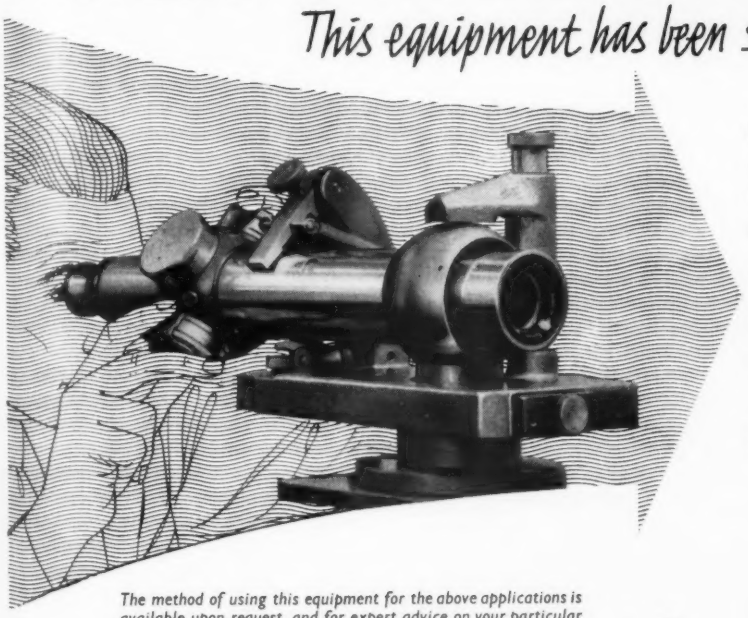

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The method of using this equipment for the above applications is available upon request, and for expert advice on your particular problem, please apply to Optical Tooling Engineers' Dept.

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supplied in densities
16.8,17.0,17.5,18.0g/cc(nominal)

- ***for screening purposes***
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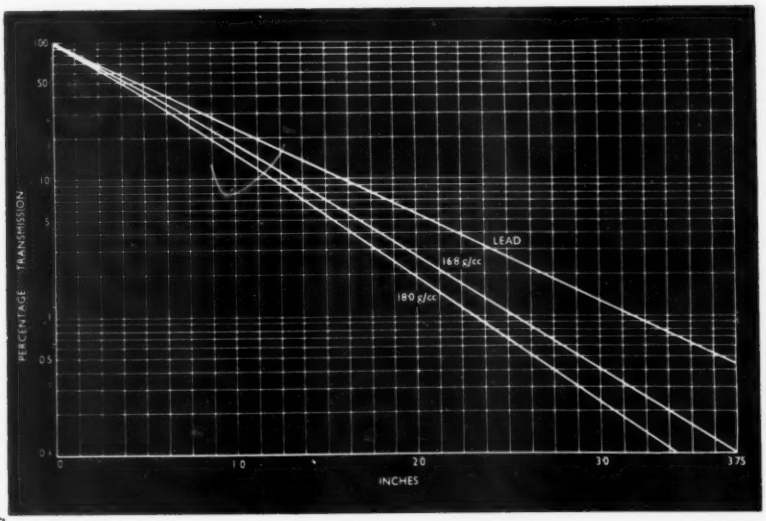
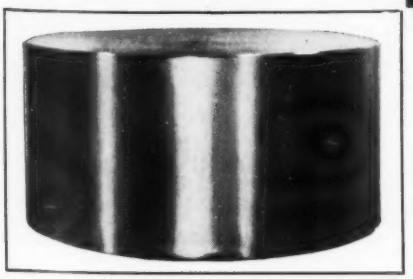


Broad beam absorption of Gamma-radiation from COBALT-60. Density: 16·8 g/cc. and 18·0 g/cc.



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Mr. Squinch says:

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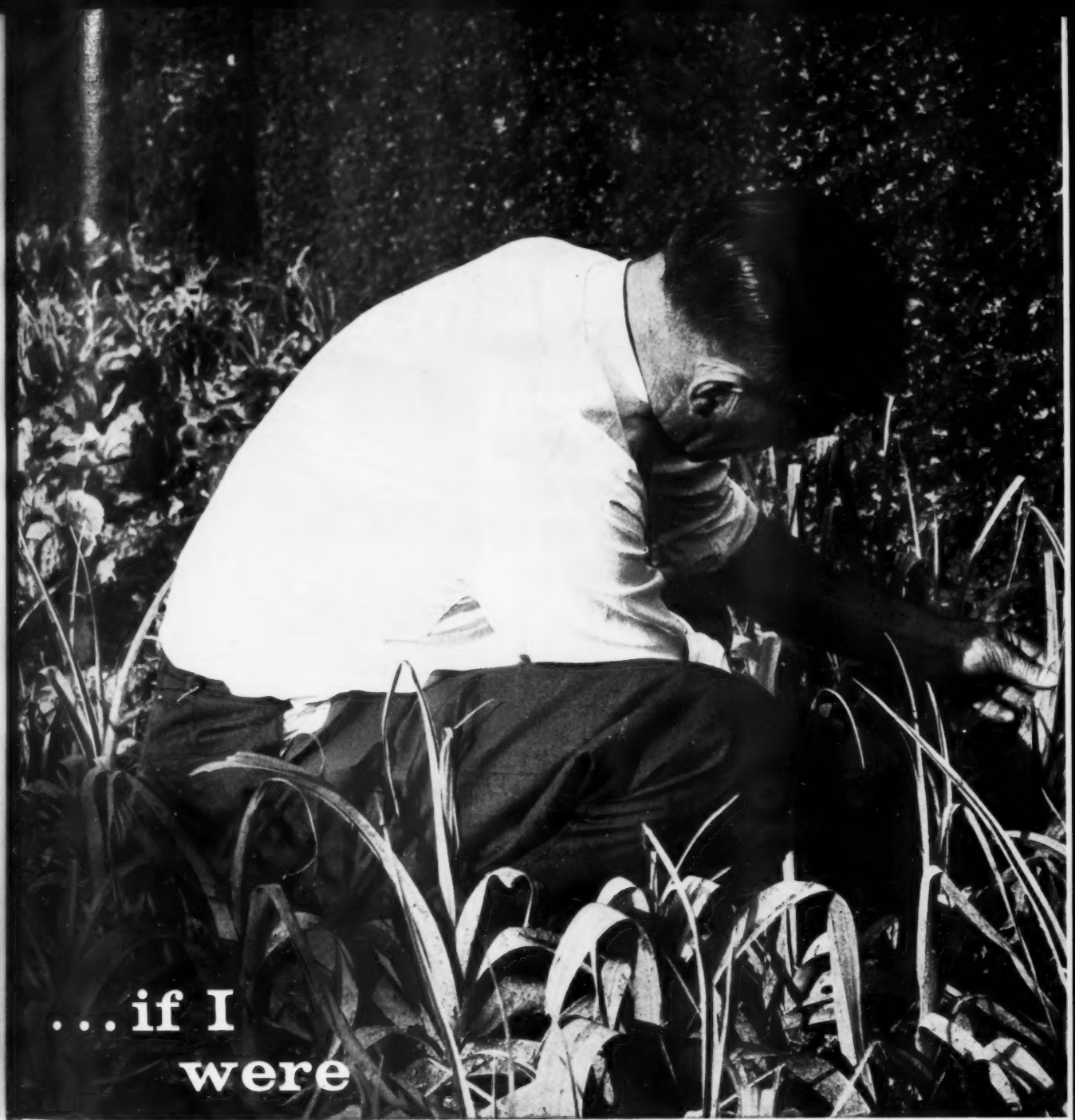

managing director

...They always say that the leaves grow greener in the other fellow's garden—but I doubt it.

"Seems to me that being a Managing Director would have its drawbacks. Having to entertain customers when I fancied a yarn with the boys and only seeing a leek when it was dished up in a tureen would drive me fair barmy inside a month.

"Mind you—don't get me wrong. If somebody offered me the job I'd have a shot at it, but deep down I feel that the boss's chair calls for a little more than most of us can give. In the 40 years I've worked for the AW Group I've learned to handle men and make a quick decision. I can talk about steel until the cows come home and I know a few tricks that the professors don't teach . . . but as for being a Managing Director . . . I reckon I'll stick to my own garden after all."

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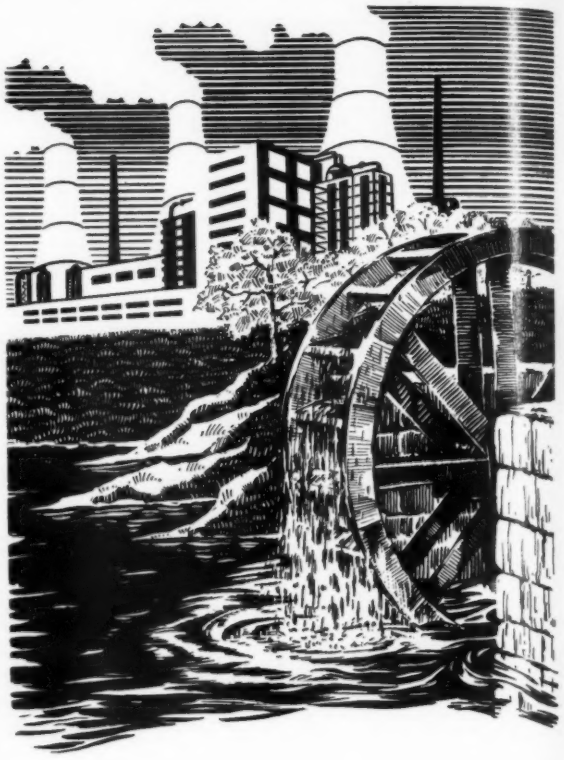

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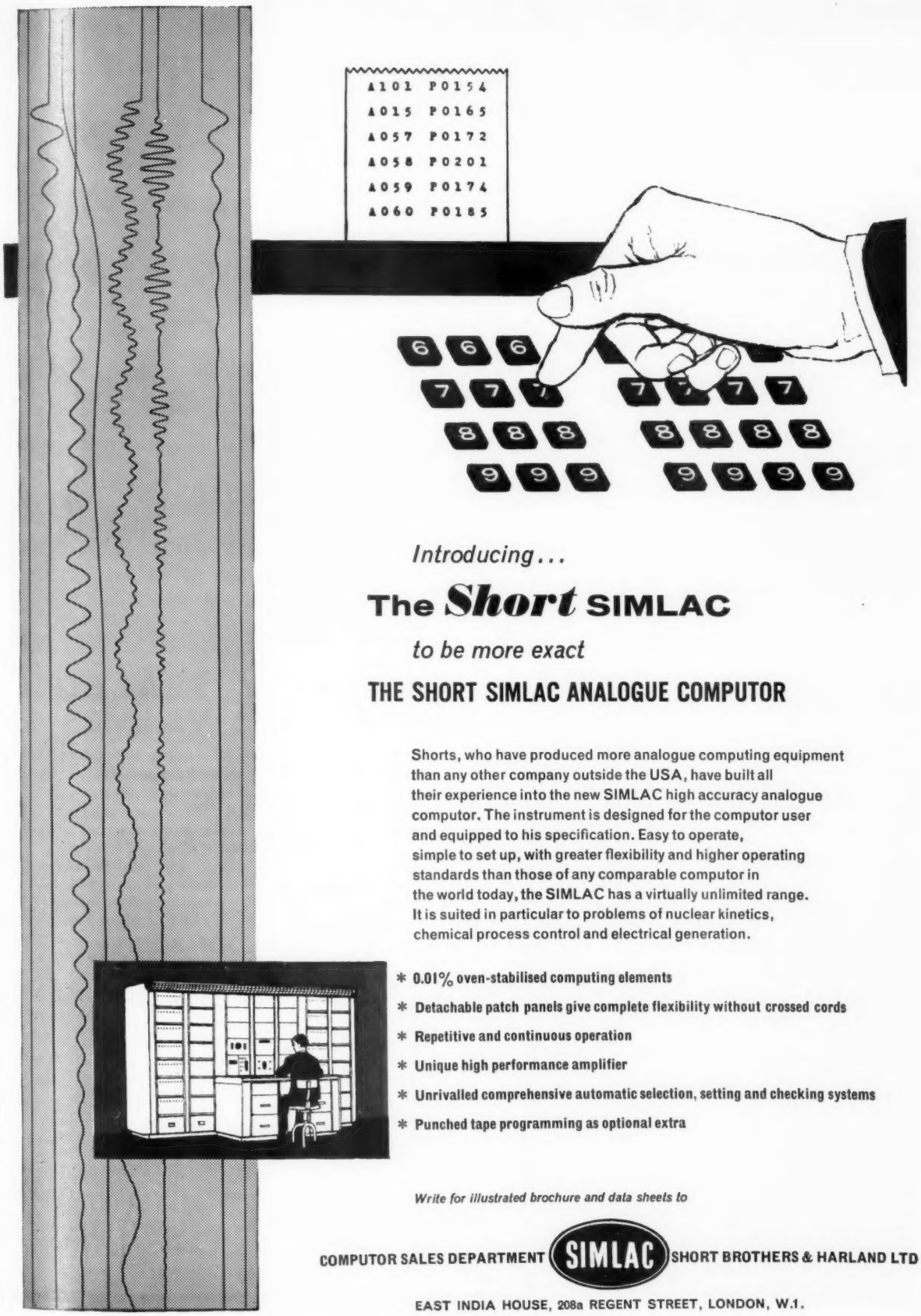

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to be more exact

THE SHORT SIMLAC ANALOGUE COMPUTOR

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the answer came from –

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Rotary pumps, diffusion pumps, valves, combined units—these are but a few from the very full range of equipment now being produced for the High Vacuum industry by N.G.N.....our technical services are being increasingly used to assist and advise on problems of High Vacuum. Why not make use of them—NOW.

SOLUTION

Type HCU Pumping Plant

By means of the two hand valves used in conjunction with the baffle valve, sequence pumping may be obtained when using the Type HCU Pumping Plant which is equipped to give Rough Pumping and Fine Pumping, isolation or Air Admittance, and water relay to protect the Diffusion Pump against water supply failure. In general, the HCU is more suitable where access to the vacuum chamber is not required for production sequence cycles, and where the plant is not likely to be left running overnight without supervision.

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High Vacuum Specialists and Electrical Engineers

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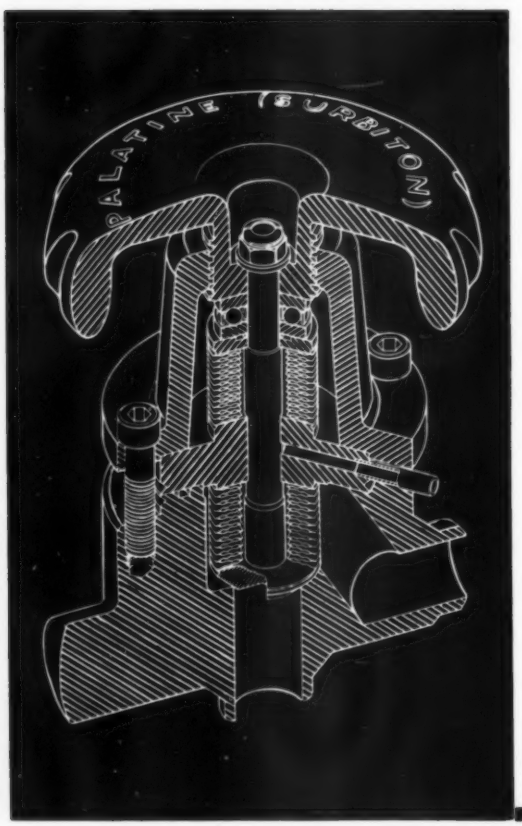

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REMOTE CONTROL VALVES OPERATED BY AIR DIAPHRAGM OR PNEUMATIC MOTORS—ELECTRIC ACTUATORS—VERY COMPACT HIGH TEMPERATURE —VACUUM—LIQUID VALVES. PORTING AND STUBS TO CUSTOMER'S REQUIREMENTS.

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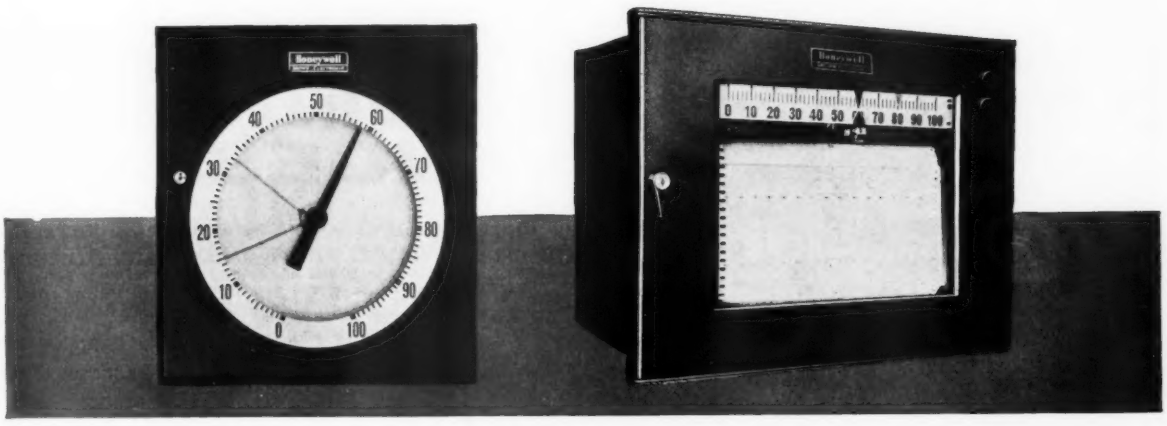
makes ElectroniK potentiometers

easier to use and maintain



Now, four great new features add new operating and servicing ease to all ElectroniK circular and strip chart potentiometers.

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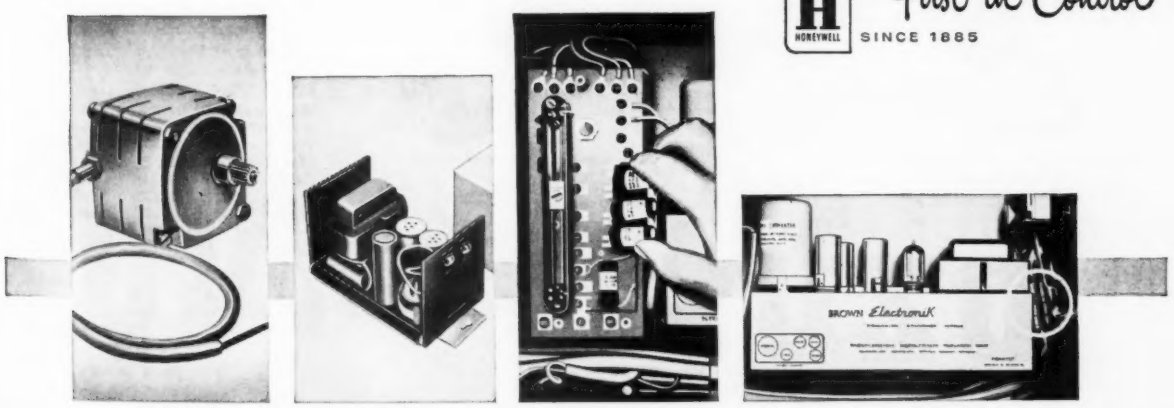

1 Balancing Motor 2 Constant Voltage Module 3 Measuring Circuit Module 4 Amplifier Module

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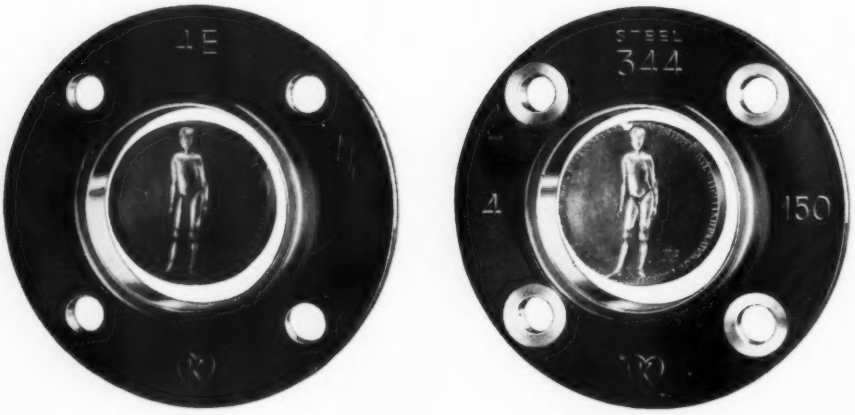

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SAFE..

- Dzus are fasteners with a world reputation for reliability. They can be fitted quite simply in any solid or laminated material regardless of thickness.
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- Dzus are the fastest fasteners with a variety of uses on Inspection Hatches and Panels, Engine Covers, Machinery Guards, Fascia Panels, Radiator Grilles and in the Electronic, Motor Vehicle, Air Conditioning, Heating and Shipbuilding Industries.

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Sales Agents in U.K., Thomas P. Headland Ltd., Melon Road, Peckham, London, S.E.15.

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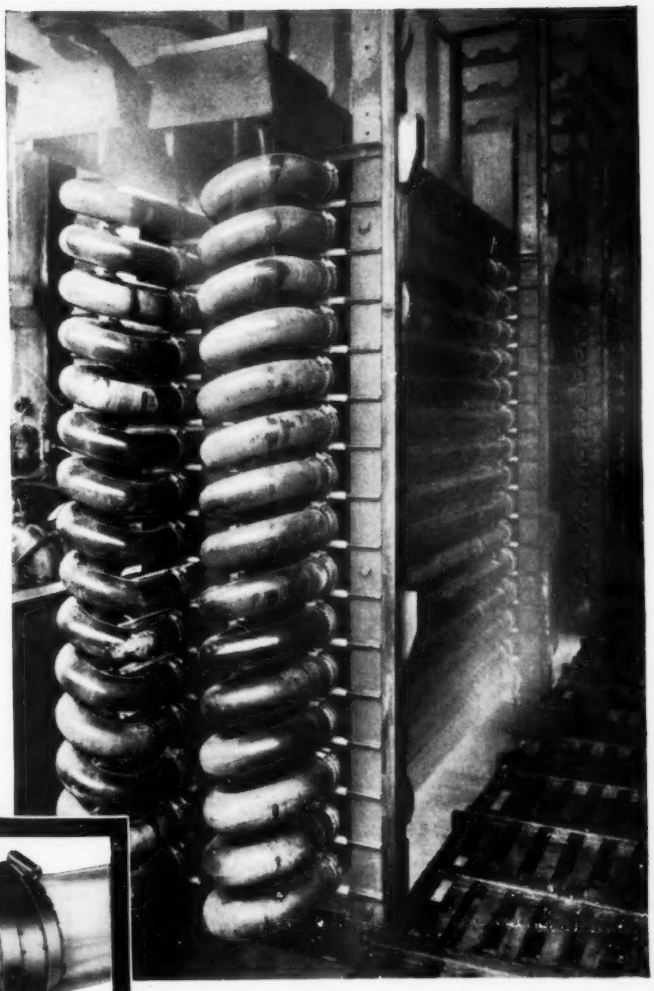
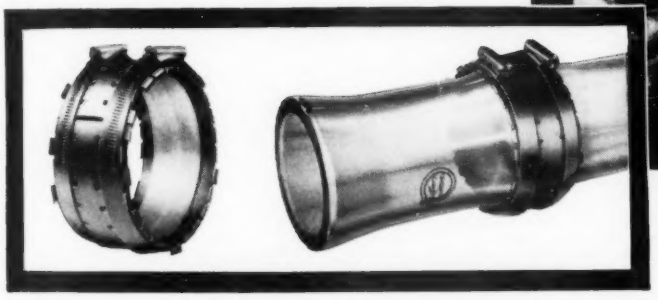
SULPHURIC ACID COOLERS IN GLASS





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More important to you is the *range* of this equipment, for by using a combination of plant and skills, we can offer a service and carry out procedures impracticable to a firm possessing a less versatile organisation.

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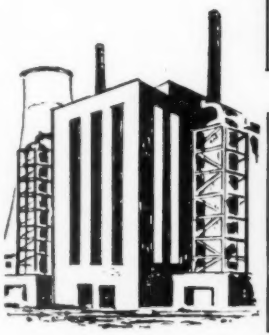

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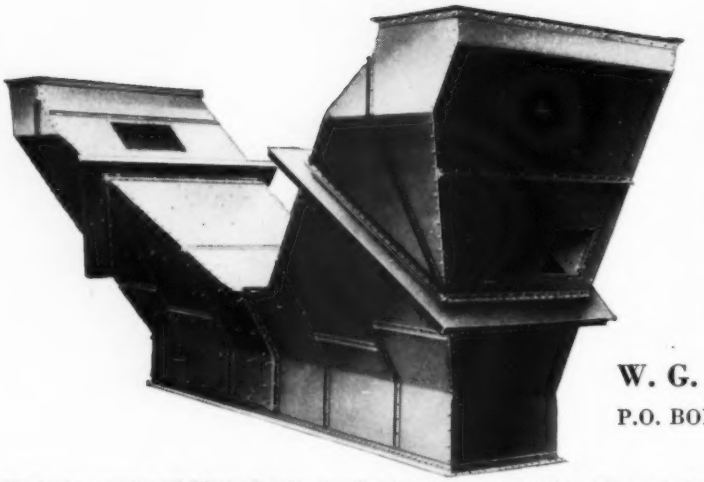

We specialise in welded or riveted fabrications in Mild Steel, Stainless Steel and Aluminium Alloys and pride ourselves on the attention paid to constructional details which ensure trouble-free service for the finished product.

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Low Heat Input makes the BIG difference

HERE'S WHY! "Eutectic Low Temperature Alloys" are exclusively based on the principle of "surface alloying" and allow better, faster, safer welds below the critical heat range; reducing to a minimum the warping, distortion and embrittlement problems associated with conventional high-heat welding methods.

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ON CAST IRON: Xyron * 2-24 (patented) gives machinable colour matching welds, 15 t.s.i. U.T.S. **without preheat!** EutecRod * 185FC is ready flux-coated depositing a fully machinable "BronzoChrom" alloy at BHN 110 which work hardens to BHN 280—ideal for rebuilding worn and broken parts!

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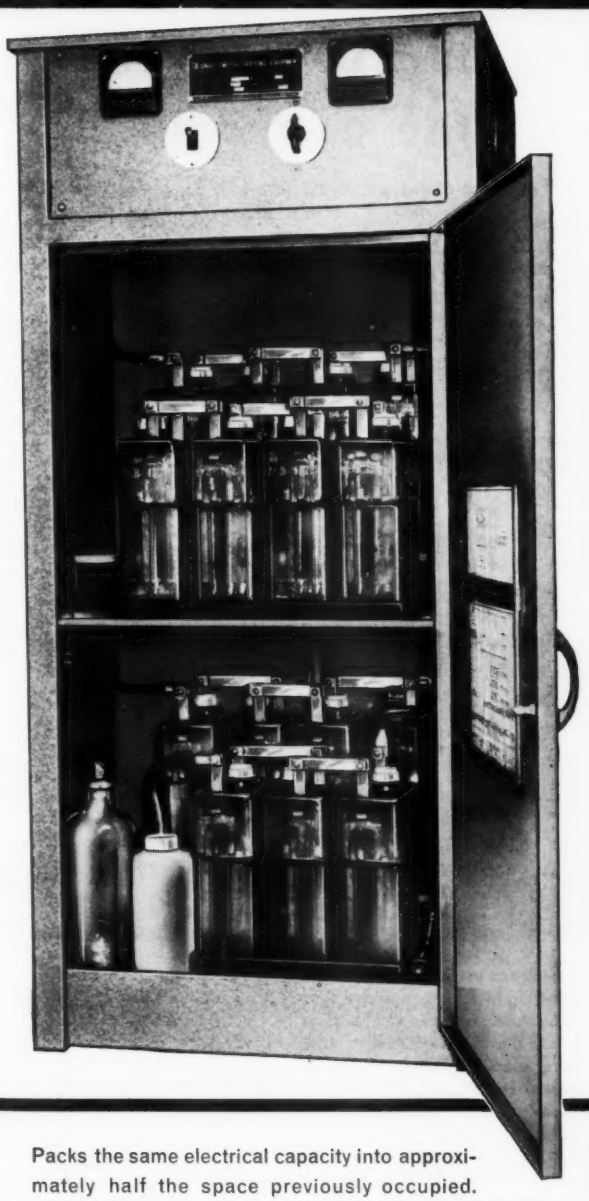
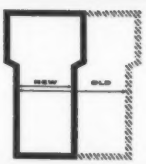
NEW TUDOR
SELF-CONTAINED SWITCH-TRIPPING EQUIPMENT



The famous Tudor switch-tripping equipment is now being constructed to an improved design, and is being supplied with either the 10Ah B.S.S. cell or the new High Performance cell of 15 or 30 Ah capacity.* The cubicles are now available either in folded sheet steel, or alternatively in a wooden cabinet fitted with a glass panelled door. The charger which is incorporated into the equipment is now suitable for both trickle and quick charging. The Tudor self-contained switch-tripping equipment is constantly at the ready in power plants, sub-stations, and many other places where loading is intermittent and an unfailing emergency supply is essential in case of temporary mains interruption. The equipment is easily maintained and throughout the years has proved unceasingly reliable.

*The new Tudor High-Performance Cell



Packs the same electrical capacity into approximately half the space previously occupied. It maintains its remarkable length of life with complete reliability, and working efficiency has been increased.

Improved features of the Tudor 'Safetylyte' Emergency Lighting Equipment

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T175

Tudor

SELF-CONTAINED SWITCH-TRIPPING EQUIPMENT

THE D.P. BATTERY CO. LTD., *manufacturers of Kathanode and Tudor Batteries* · **BAKEWELL, DERBYSHIRE**
Telephone Bakewell 581-5

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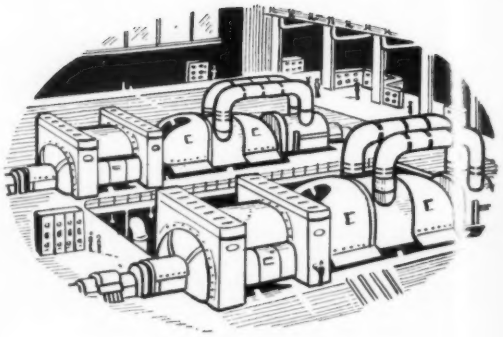

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Instruments, Electronics & Automation Exhibition, Olympia, May 23—28, 1960. Visit Stand No. F 259. Tickets available from Cambridge Instrument Co. Ltd.

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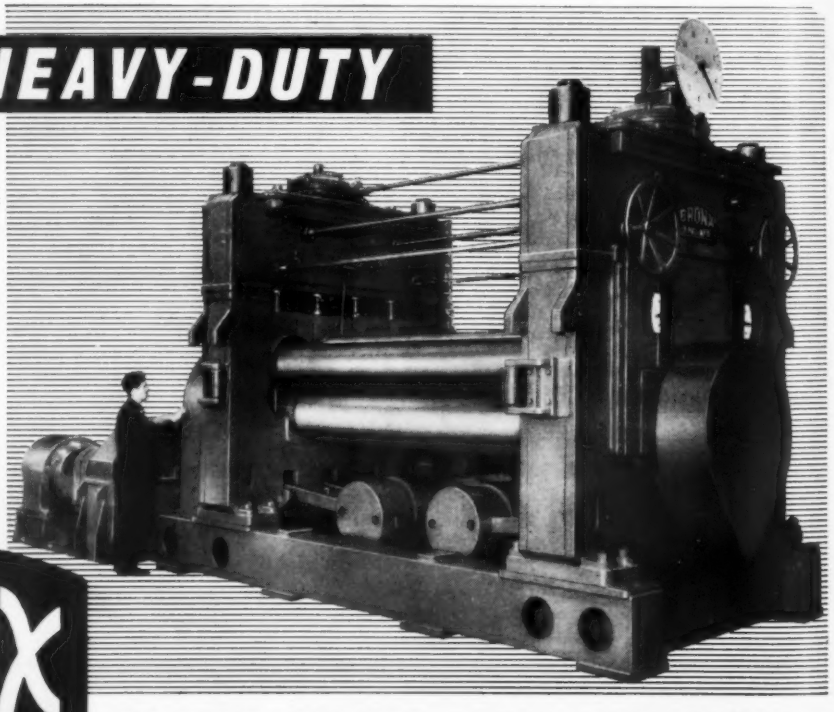
International Machine Tool Exhibition Olympia, London Stand 107



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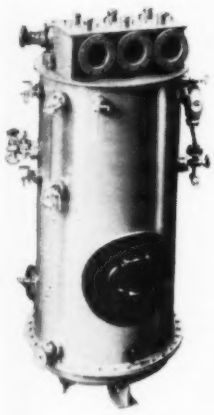

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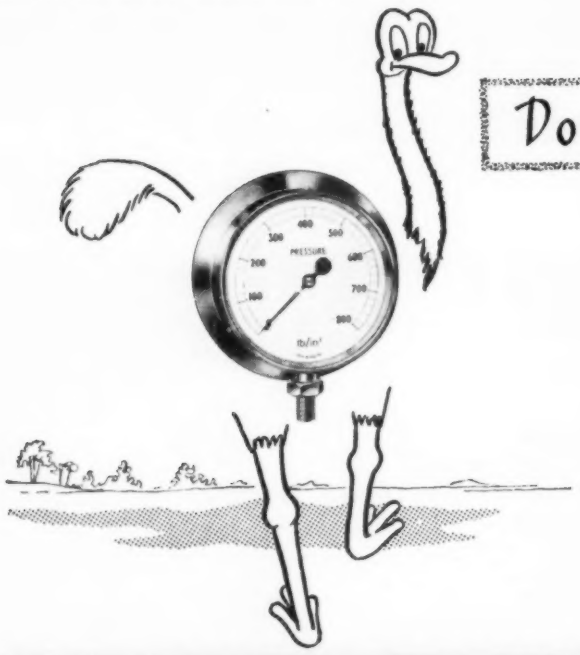

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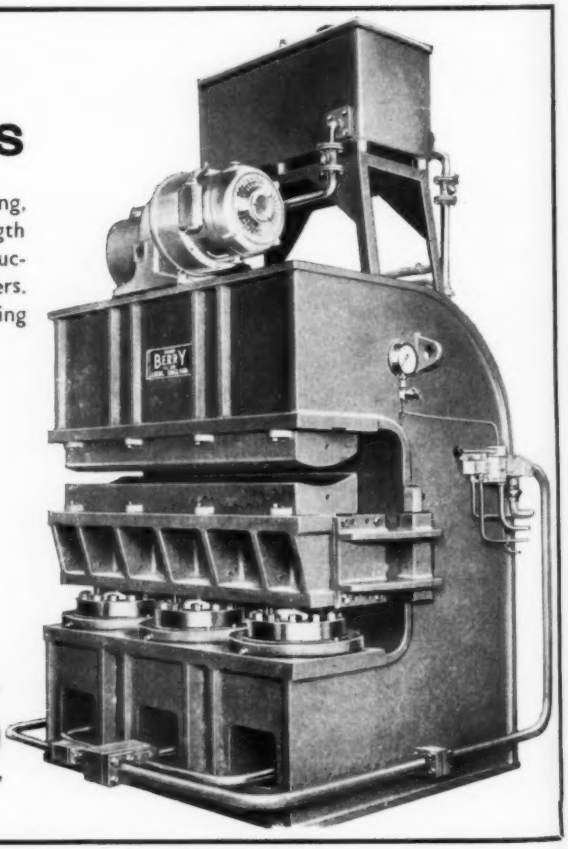

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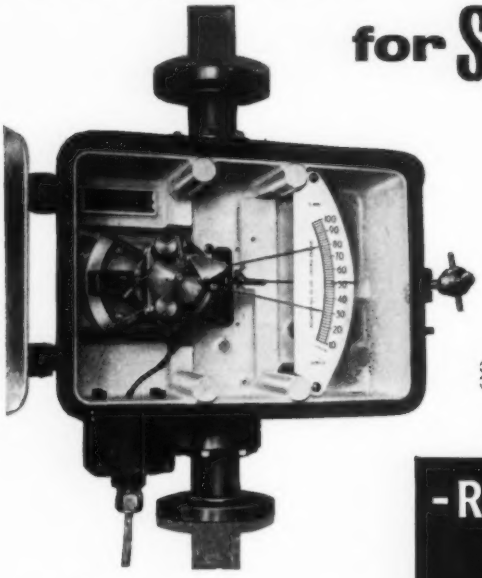

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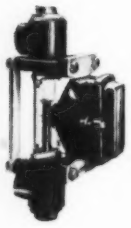

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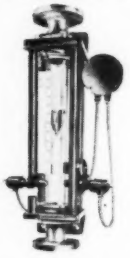

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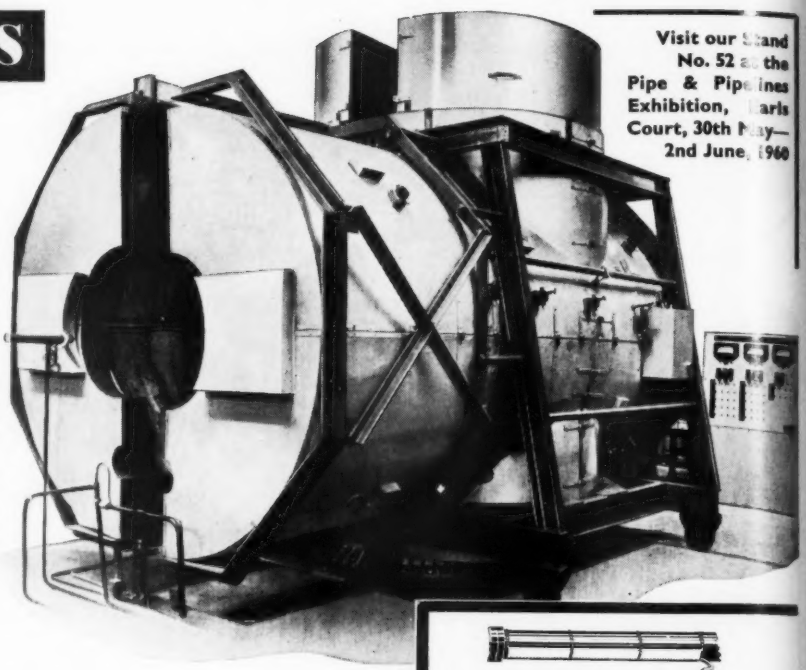

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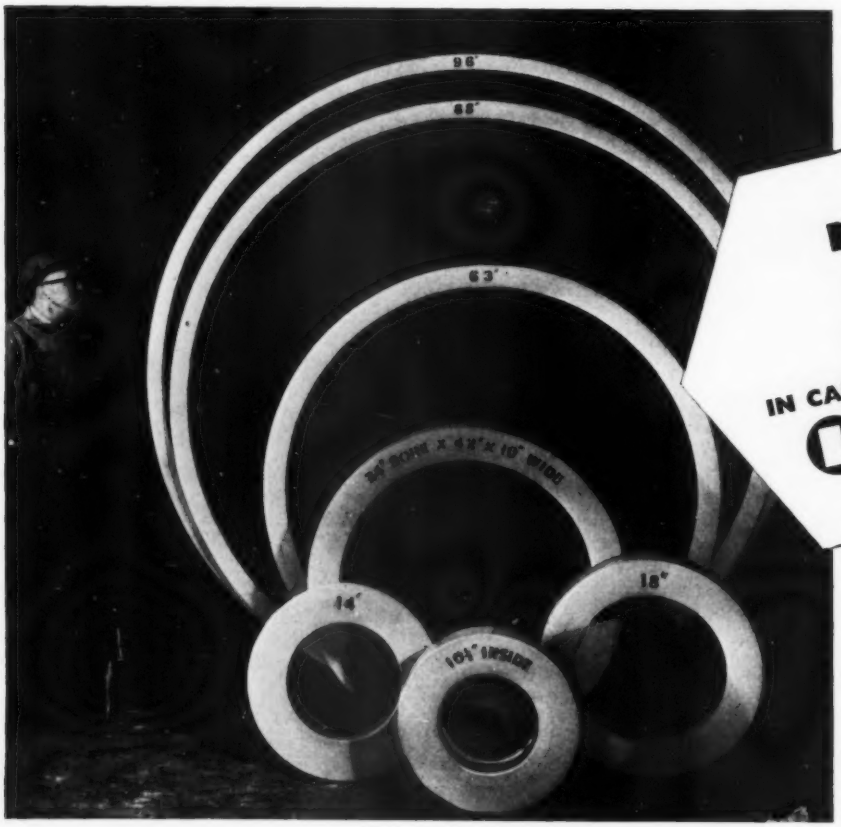

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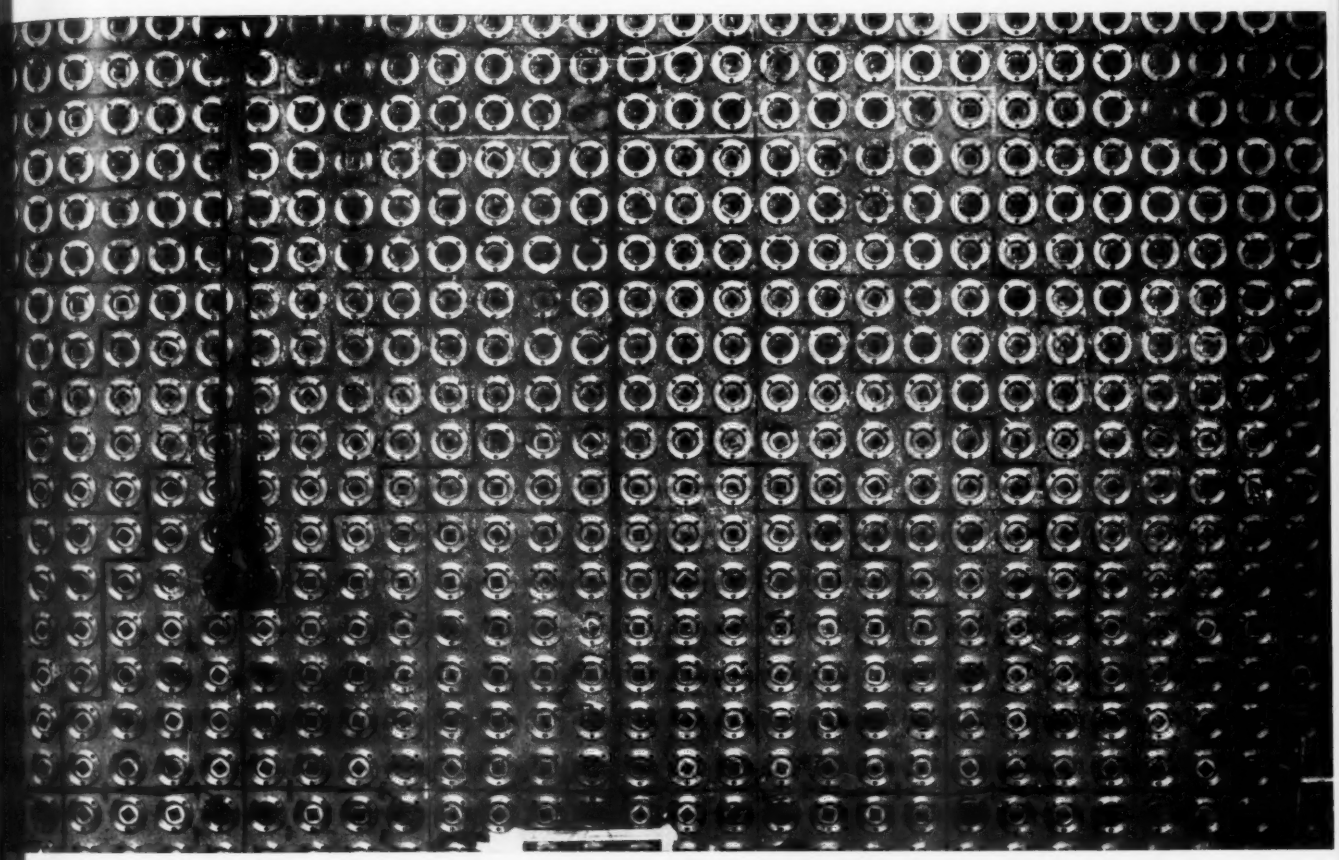

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57 G.P.H./150 P.S.I. — ¼ H.P.

ECONOMY Low current — requiring simple, inexpensive switchgear.

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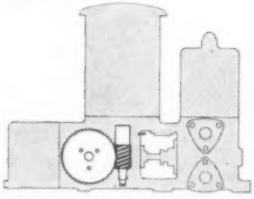

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Suitable for all climatic conditions

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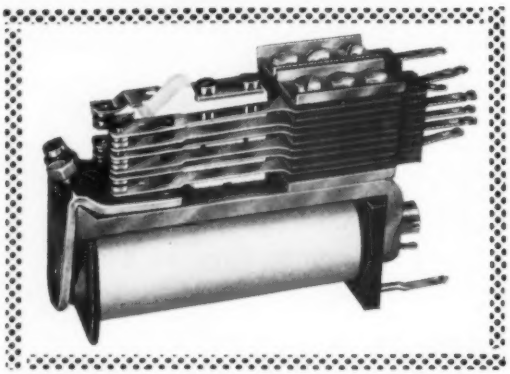

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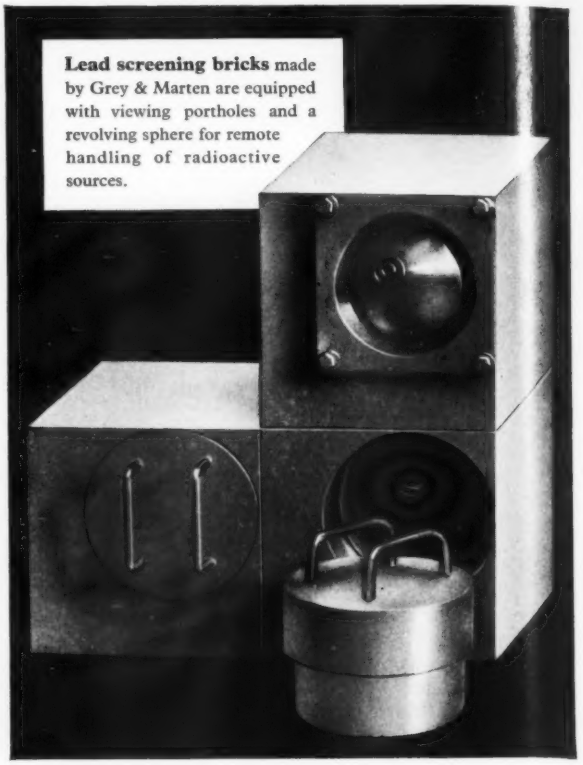

Lead screening bricks made by Grey & Marten are equipped with viewing portholes and a revolving sphere for remote handling of radioactive sources.

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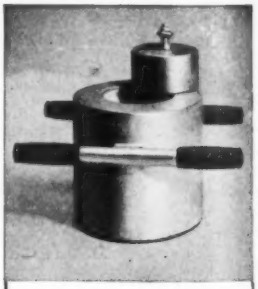

Storage pot typical of those used in standard safes not already fitted with lead protection, affords economical storage for radio-active material.

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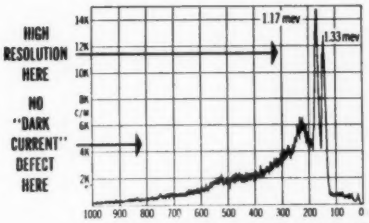
Combines Better Resolution With Greater Precision Over Wider Range Than Any Other System At Any Price



Actual spectrogram of Cobalt-60 made with a GSS-1. Window No. 3. Time constant: 2 sec.

A complete gamma spectrometer system NMC model GSS-1

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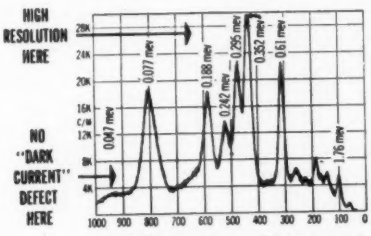

Actual spectrogram of Radium made with a GSS-1. Four runs over a period of 20 hours with no adjustment of instrument between runs, demonstrating utmost stability. Range: 30,000 C/M. Time constant: 3 sec.

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International Office:
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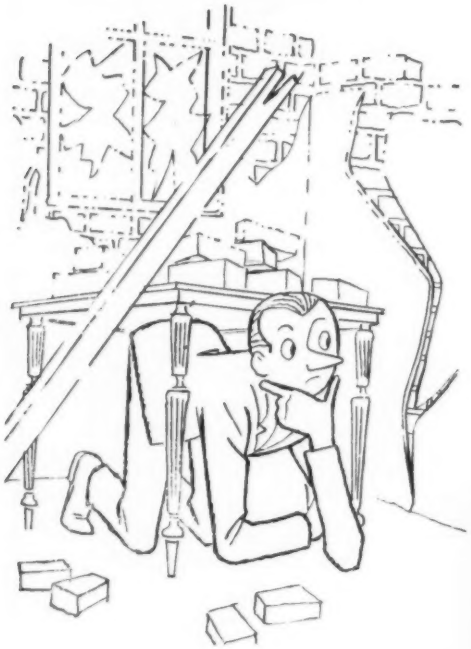

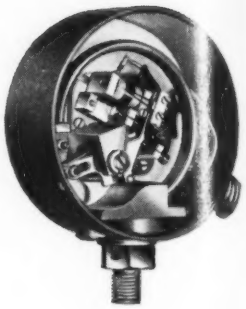

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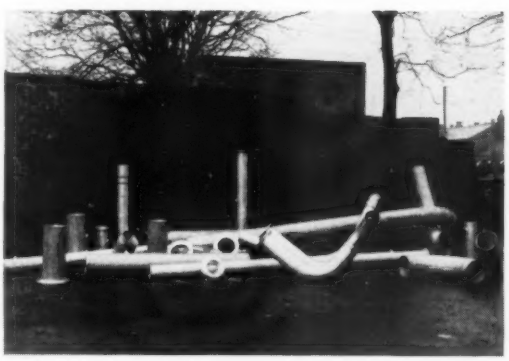

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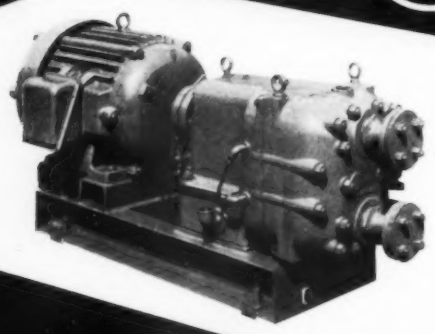

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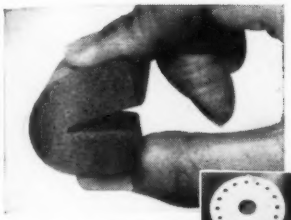

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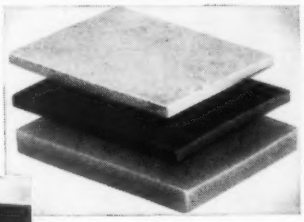

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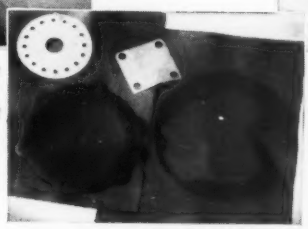

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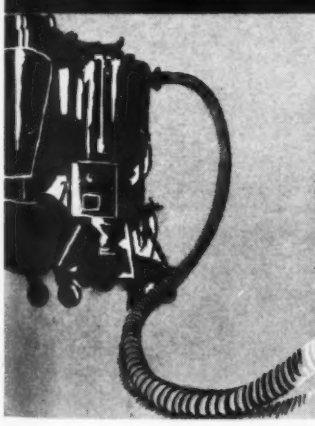

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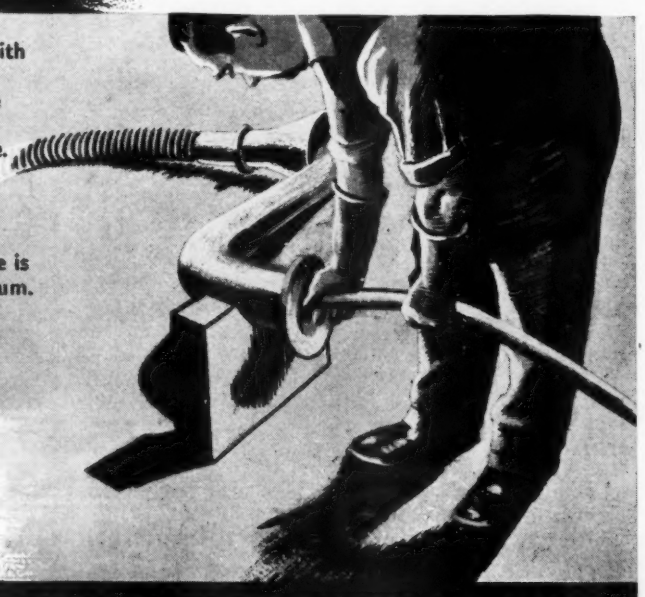

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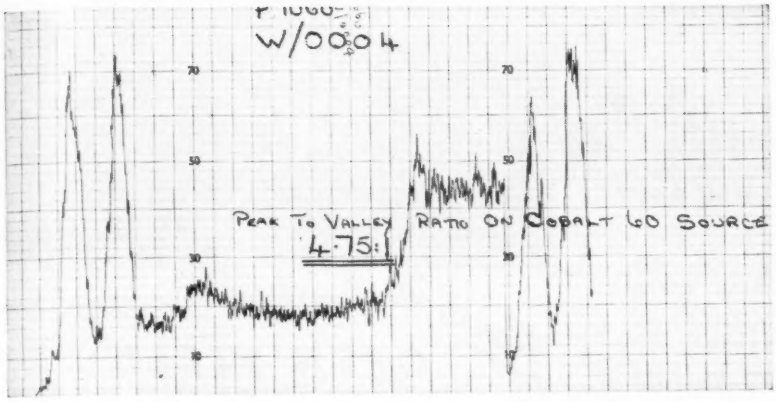

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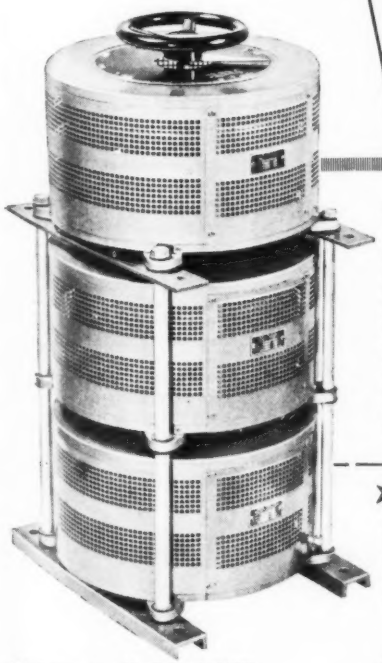

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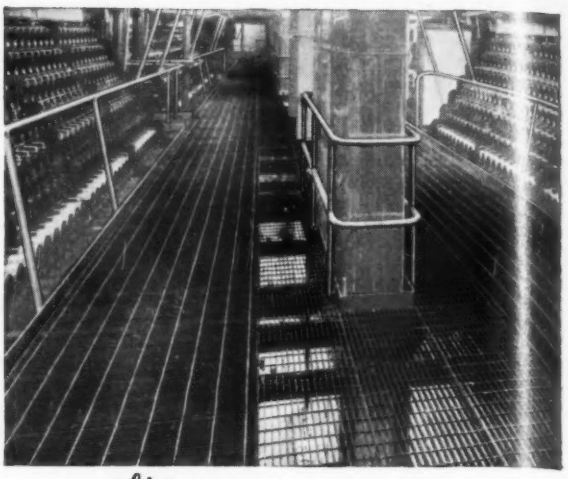

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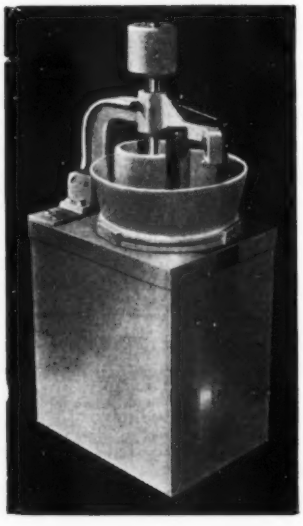

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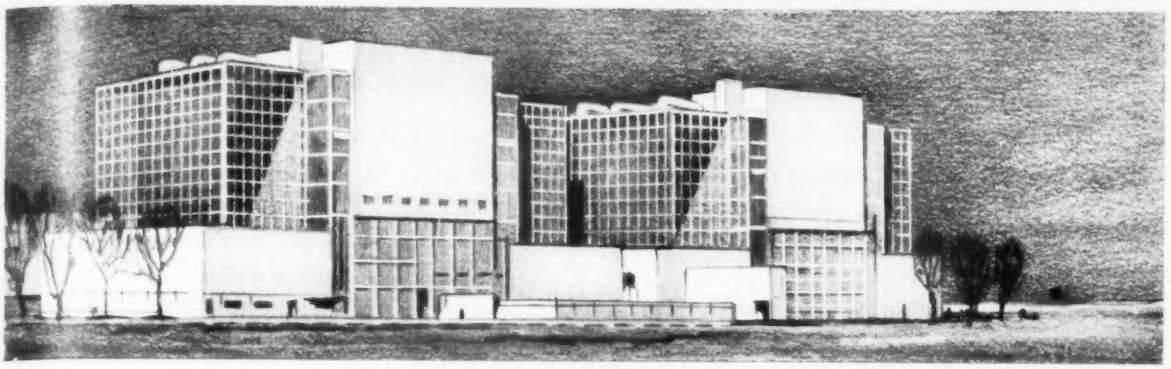

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The fifth course on "The Control and Instrumentation of Reactors" will be held at Durley Hall, Bournemouth, Hampshire, from the 12th to 23rd September, 1960, inclusive.

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The fee for the course will be fifty guineas, exclusive of accommodation.

Application forms and further details can be had from:—
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Standard Course No. 21

The next Standard Course will be held from the 29th August to 16th December, 1960, inclusive. The fee for the course is £250, exclusive of accommodation.
This course is intended primarily for engineers and physicists whose main interest is in reactor design.

Senior Technical Executives' Course No. 11

The course will be held from the 26th September to 7th October, 1960, inclusive. The fee for the course is fifty guineas, exclusive of accommodation.
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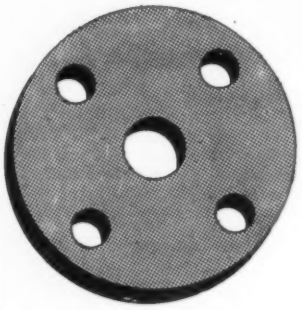

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Nukem will take over the existing research and production programme of the Degussa Nuklear Gruppe, which covers a wide range of uranium and thorium processing and fabricating activities related to the nuclear programmes of a number of countries.

Mallinckrodt Chemical Works, through its subsidiary Mallinckrodt Nuclear Corporation, a U.S. company prominent in the nuclear fuel field, is also a shareholder in the new company and has concluded a technical collaboration agreement with Nukem providing for exchange of information on the processing of nuclear fuel materials.

Nukem will co-operate closely with Rio Tinto's uranium mining interests and with Rio Tinto Dow Limited, a company specialising in uranium and thorium processing.

Nuklear-Chemie und -Metallurgie Gesellschaft m.b.H., Wolfgang bei Hanau (Main)

Deutsche Gold- und Silber-Scheideanstalt vormals Roessler (Degussa), Weissfrauenstrasse 9, Frankfurt (Main)

Rio Tinto Management Services (U.K.) Limited, Barrington House, 59 Gresham Street, London, E.C.2

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TOKAI-MURA

At Tokai-Mura, 70 miles north-east of Tokyo, The General Electric Company Limited of England is to build Japan's first nuclear power station. This 150 MW station will be powered by a single gas-cooled graphite-moderated reactor of the same basic type as the two which are being built by G.E.C. at Hunterston in Scotland. In producing a design to ensure the safety of the installation even under severe earthquake conditions, G.E.C. and her associate Simon-Carves Ltd., have brought to bear the results of much experimental work. For example, models of the pressure vessel mounted on a supporting skirt were subjected to horizontal loads such as would arise from earthquake shock.

Unique protective devices will be provided capable of effective operation even if the core should be severely damaged. In addition to the normal control rod system there is a unique arrangement of boron steel balls which would be released into the channels in the core by seismic pick-ups outside the station or by displacement of the pressure vessel, the core itself, the grid or various other critical parts of the reactor.

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